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Interactive systems for digital television distribution

Interaction channel for local multipoint distribution systems

ITU-T Recommendation J.116

(Formerly CCITT Recommendation)

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TRANSMISSION OF TELEVISION, SOUND PROGRAMME AND OTHER MULTIMEDIA SIGNALS

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ITU-T Recommendation J.116

Interaction channel for local multipoint distribution systems

Summary

This Recommendation is the baseline specification for the provision of an interaction channel for Local Multipoint Distribution Systems (LMDS) networks as a digital broadcasting delivery medium. It makes provision for bidirectional data over wireless access for interactive services.

This Recommendation contains Annexes A and B in recognition of the different existing media environments.

It is recommended that for the introduction of fast Internet access and/or interactive cable television services, the systems in this Recommendation should be used to achieve the benefits of economies of scale and facilitate interoperability.

Source

ITU-T Recommendation J.116 was prepared by ITU-T Study Group 9 (1997-2000) and approved under the WTSC Resolution 1 procedure on 18 May 2000.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Introduction

Digital television services have been established in many countries and the benefits of extending these to provide interactive services are widely recognised. Wireless distribution systems are particularly suited for the implementation of bidirectional data services.

Whilst Annexes A and B reflect the different environments there is substantial commonality. The services may include fast Internet access and/or interactive cable television. The transmission protocols supported include, but are not limited to, IP and ATM. The reference architectures are all based on ITU-T J.110. In each case downstream transmission involves optional constant bit rate streams protected by scrambling and forward error correction, with multiplexing such that a head end can support a large number of remote stations (see Annexes A and B). Upstream transmission from the stations also involves a similar multiplex for which a MAC (Media Access Control) layer manages access on a contention or contentionless basis (see Annexes A and B).

Some information on the wireless path is given in Appendix I by way of illustration. Carrier frequencies for the wireless path are the responsibility of the ITU Radiocommunication Sector, where relevant Recommendations to be read in conjunction with this Recommendation are under study.

It should be noted that the annexes to this Recommendation describe different variations of the same protocol layers. Connectivity between these variations, however, can be supported by telecommunications and computer standards in the public domain which are well established and widely used.

This Recommendation is complementary to ITU-R F.1499. Both ITU-R Recommendation F.1499 and ITU-T Recommendation J.116 should be considered in their totality when implementing BWA systems.

ITU-T Recommendation J.116

Interaction channel for local multipoint distribution systems

1 Scope

This Recommendation is the baseline specification for the provision of the interactive channel for Local Multipoint Distribution Systems (LMDS) networks. This Recommendation, together with its Annexes A and B, is based on ITU-T J.112. The annexes in this Recommendation are intended to be read in conjunction with the relevant wireless distribution Recommendations which are under study in the ITU Radiocommunication Sector.

The two annexes represent complementary approaches which reflect existing media environments. Annex A is based on work associated with interfaces to TV receivers, whilst Annex B is based on work associated with PC modems. However, there is substantial commonality in the services and protocols supported. The reference architectures are also based on ITU-T J.110. There is therefore the possibility that, in application, the features chosen for use with a particular wireless distribution system may take advantage of the economies of scale derived from implementation of subsystems described in the separate annexes.

This Recommendation is complementary to ITU-R F.1499. Both ITU-R F.1499 and ITU-T J.116 should be considered in their totality when implementing BWA systems.

2 References

2.1 Normative References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

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– ITU-T J.110 (1997), *Basic principles for a worldwide common family of systems for the provision of interactive television services.*

– ITU-T J.111 (1998), *Network independent protocols for interactive systems.*

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- ITU-T V.32 (1993), *A family of 2-wire, duplex modems operating at data signalling rates of up to 9600 bit/s for use on the general switched telephone network and on leased telephone-type circuits.*
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- ISO/IEC 8802-3:1996, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.*
- ISO/IEC 15802-1:1995, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Common specifications – Part 1: Medium Access Control (MAC) service definition.*
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2.2 Informative references

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- MCNS3, Data-Over-Cable Service Interface Specifications, Cable Modem Termination System – Network-Side Interface Specification SP-CMTS-NSI-I01-960702. (Ref. Annex B.)
- MCNS4, Data-Over-Cable Service Interface Specifications, Cable Modem to Customer Premises Equipment Interface Specification SP-CMCI-I01-960702. (Ref. Annex B.)
- MCNS5, Data-Over-Cable Service Interface Specifications, Operations Support System Interfaces SP-OSSI-I01-970403. (Ref. Annex B.)

– MCNS6, Data-Over-Cable Service Interface Specifications, Cable Modem Telephone Return Interface Specification SP-CMTRI-I01-970804. (Ref. Annex B.)

– MCNS7, Data-Over-Cable Service Interface Specifications, Removable Security Module Interface Specifications, SP-RSMI-I01-980204. (Ref. Annex B.)

– MCNS8, Data-Over-Cable Service Interface Specifications, Baseline Privacy Interface SP-BPI-I01-970609. (Ref. Annex B.)

– NCTA, NCTA Recommended Practices for measurement on Cable Television Systems – National Cable Television Association, Washington DC, 2nd Edition, revised October 1993. (Ref. Annex B.)

– SMS, The Spectrum Management Application (SMA) and the Common Spectrum Management Interface (CSMI), Time Warner Cable, 24 December 1995. (Ref. Annex B.)

3 Terms, definitions and abbreviations

3.1 Terms and definitions

3.1.1 address resolution protocol: A protocol of the IETF for converting network addresses to 48-bit Ethernet addresses.

3.1.2 asynchronous transfer mode: A protocol for the transmission of a variety of digital signals using uniform 53-byte cells.

3.1.3 availability: Is the long-term ratio of the actual RF channel operation time to scheduled RF channel operation time (expressed as a percent value) and is based on a bit error rate (BER) assumption.

3.1.4 bridge protocol data unit (BDU): Spanning tree protocol messages as defined in ISO/IEC 15802-3.

3.1.5 broadcast addresses: A predefined destination address that denotes the set of all data network service access points.

3.1.6 burst error second: Any Errored Second containing at least 100 errors.

3.1.7 BWA BTS modem: Broadband Wireless Access Base Transceiver Station modem. One or more downstream demodulators and their corresponding upstream modulators.

3.1.8 BWA CPE modem: Broadband Wireless Access Customer Premises Equipment Modem.

3.1.9 carrier hum modulation: The peak-to-peak magnitude of the amplitude distortion relative to the RF carrier signal level due to the fundamental and low-order harmonics of the power-supply frequency.

3.1.10 carrier-to-noise ratio (C/N or CNR): The square of the ratio of the root mean square (rms) of the voltage of the digitally-modulated RF carrier to the rms of the continuous random noise voltage in the defined measurement bandwidth. (If not specified explicitly, the measurement bandwidth is the symbol rate of the digital modulation.)

3.1.11 cross-modulation: A form of television signal distortion where modulation from one or more television channels is imposed on another channel or channels.

3.1.12 customer premises equipment (CPE): Equipment at the end user's premises; may be provided by the end user or the service provider.

3.1.13 customer: See End User.

3.1.14 data link layer: Layer 2 in the Open Systems Interconnection (OSI) architecture; the layer that provides services to transfer data over the transmission link between open systems.

3.1.15 downstream: The direction of transmission from the BTS to the subscriber.

3.1.16 dynamic host configuration protocol (DHCP): An Internet protocol used for assigning network-layer (IP) addresses.

3.1.17 dynamic range: The ratio between the greatest signal power that can be transmitted over a multichannel analogue transmission system without exceeding distortion or other performance limits, and the least signal power that can be utilised without exceeding noise, error rate or other performance limits.

3.1.18 end user: A human being, organisation, or telecommunications system that accesses the network in order to communicate via the services provided by the network.

3.1.19 errored second: Any one second interval containing at least one bit error.

3.1.20 fibre distributed data interface (FDDI): A fibre-based LAN standard.

3.1.21 fibre node: A point of interface between a fibre trunk and the coaxial distribution.

3.1.22 forward channel: The direction of RF signal flow away from the BTS toward the end user; synonymous to Downstream.

3.1.23 group delay: The difference in transmission time between the highest and lowest of several frequencies through a device, circuit or system.

3.1.24 guard time: Minimum time allocated between bursts in the upstream, referenced from the symbol centre of the last symbol of a burst to the symbol centre of the first symbol of the following burst.

3.1.25 headend: The central location on the BWA network that is responsible for injecting broadcast video and other signals in the downstream direction. See also Master Headend, Distribution Hub.

3.1.26 header: Protocol control information located at the beginning of a protocol data unit.

3.1.27 impulse noise: Noise characterised by non-overlapping transient disturbances.

3.1.28 interleave: An error correction method that enables the correction of burst noise induced errors.

3.1.29 Internet control message protocol (ICMP): An Internet network-layer protocol.

3.1.30 Internet protocol (IP): An Internet network-layer protocol, defined by the IETF.

3.1.31 latency: The time, expressed in quantity of symbols, taken for a signal element to pass through a device.

3.1.32 layer: A subdivision of the Open Systems Interconnection (OSI) architecture, constituted by subsystems of the same rank.

3.1.33 local area network (LAN): A non-public data network in which serial transmission is used for direct data communication among data stations located on the user's premises.

3.1.34 logical link control (LLC) procedure: In a local area network (LAN) or a Metropolitan Area Network (MAN), that part of the protocol that governs the assembling of data link layer frames and their exchange between data stations, independent of how the transmission medium is shared.

3.1.35 MAC service access point: Is an attachment to a MAC-sublayer domain.

3.1.36 master headend: A headend which collects television program material from various sources by satellite, microwave, fibre and other means, and distributes this material to Distribution Hubs in the same metropolitan or regional area.

3.1.37 mean time to repair (MTTR): The MTTR is the average elapsed time from the moment a loss of RF channel operation is detected up to the moment the RF channel operation is fully restored.

3.1.38 media access control (MAC) address: The "built-in" hardware address of a device connected to a shared medium.

3.1.39 media access control (MAC) procedure: In a subnetwork, that part of the protocol that governs access to the transmission medium independent of the physical characteristics of the medium, but taking into account the topological aspects of the subnetworks, in order to enable the exchange of data between nodes. MAC procedures include framing, error protection, and acquiring the right to use the underlying transmission medium.

3.1.40 media access control (MAC) sublayer: The part of the data link layer that supports topology dependent functions and uses the services of the Physical Layer to provide services to the Logical Link Control (LLC) sublayer.

3.1.41 mini-slot: A mini-slot is an integer multiple of 6.25-microsecond increments. The relationship between mini-slots, bytes and time ticks is described in B.6.5.4.

3.1.42 multipoint access: User access in which more than one terminal equipment is supported by a single network termination.

3.1.43 multipoint connection: A connection among more than two data network terminations.

3.1.44 network layer: Layer 3 in the Open Systems Interconnection (OSI) architecture; the layer that provides services to establish a path between open systems.

3.1.45 network management: The functions related to the management of data link layer and physical layer resources and their stations across the data network supported by the hybrid fibre/coax system.

3.1.46 open systems interconnection (OSI): A framework of ISO standards for communication between different systems made by different vendors, in which the communications process is organised into seven different categories that are placed in a layered sequence based on their relationship to the user. Each layer uses the layer immediately below it and provides a service to the layer above. Layers 7 through 4 deal with end-to-end communication between the message source and destination, and layers 3 through 1 deal with network functions.

3.1.47 organisationally unique identifier (OUI): A three-octet IEEE assigned identifier that OUI can be used to generate Universal LAN MAC addresses and Protocol Identifiers per ANSI/IEEE Std 802 for use in Local and Metropolitan Area Network applications.

3.1.48 packet identifier (PID): A unique integer value used to identify elementary streams of a program in a single- or multi-program MPEG-2 stream.

3.1.49 physical (PHY) layer: Layer 1 in the Open Systems Interconnection (OSI) architecture; the layer that provides services to transmit bits or groups of bits over a transmission link between open systems and which entails electrical, mechanical and handshaking procedures.

3.1.50 physical media dependent (PMD) sublayer: A sublayer of the Physical Layer which is concerned with transmitting bits or groups of bits over particular types of transmission link between open systems and which entails electrical, mechanical and handshaking procedures.

3.1.51 program specific information (PSI): In MPEG-2, normative data necessary for the demultiplexing of Transport Streams and the successful regeneration of programs.

3.1.52 program stream: In MPEG-2, a multiplex of variable-length digital video and audio packets from one or more program sources having a common time-base.

3.1.53 protocol: A set of rules and formats that determines the communication behaviour of layer entities in the performance of the layer functions.

3.1.54 quadrature amplitude modulation (QAM): A method of modulating digital signals onto a radio-frequency carrier signal involving both amplitude and phase coding.

3.1.55 quaternary phase-shift keying (QPSK): A method of modulating digital signals onto a radio-frequency carrier signal using four phase states to code two digital bits.

3.1.56 radio frequency (RF): Refers to electromagnetic signals typically in the range 5 to 40 000 MHz.

3.1.57 reed solomon code: A forward error correction code located before interleaving that enables correction of errors induced by burst noise.

3.1.58 return loss: The parameter describing the attenuation of a guided wave signal (e.g. via a coaxial cable) returned to a source by a device or medium resulting from reflections of the signal generated by the source.

3.1.59 reverse channel: The direction of signal flow towards the BTS, away from the subscriber; equivalent to Upstream.

3.1.60 roll off: A coefficient of cosine roll off function that determines the frequency characteristics of the filter.

3.1.61 routeing information protocol (RIP): A protocol of the IETF for exchanging routeing information about IP networks and subnets.

3.1.62 RS: Reed Solomon

3.1.63 service access point (SAP): The point at which services are provided by one layer, or sublayer, to the layer immediately above it.

3.1.64 service data unit (SDU): Information that is delivered as a unit between peer service access points.

3.1.65 simple network management protocol (SNMP): A network management protocol of the IETF.

3.1.66 sublayer: A subdivision of a layer in the Open Systems Interconnection (OSI) reference model.

3.1.67 subnetwork access protocol (SNAP): An extension of the LLC header to accommodate the use of IEEE 802 type networks as IP networks.

3.1.68 subnetwork: Subnetworks are physically formed by connecting adjacent nodes with transmission links.

3.1.69 subscriber: See End User.

3.1.70 subsystem: An element in a hierarchical division of an open system that interacts directly with elements in the next higher division or the next lower division of that open system.

3.1.71 systems management: Functions in the application layer related to the management of various Open Systems Interconnection (OSI) resources and their status across all layers of the OSI architecture.

3.1.72 tick: Time intervals that are the reference for upstream mini-slot definition and upstream transmission times.

3.1.73 transit delay: The time difference between the instant at which the first bit of a PDU crosses one designated boundary, and the instant at which the last bit of the same PDU crosses a second designated boundary.

3.1.74 transmission control protocol (TCP): A transport-layer Internet protocol which ensures successful end-to-end delivery of data packets without error, as defined by the IETF.

3.1.75 transmission convergence sublayer: A sublayer of the Physical Layer that provides an interface between the Data Link Layer and the PMD Sublayer.

3.1.76 transmission link: The physical unit of a subnetwork that provides the transmission connection between adjacent nodes.

3.1.77 transmission medium: The material on which information signals may be carried; e.g. wireless, optical fibre, coaxial cable, and twisted wire pairs.

3.1.78 transmission system: The interface and transmission medium through which peer physical layer entities transfer bits.

3.1.79 transmit on/off ratio: In multiple-access systems, the ratio between the signal powers sent to line when transmitting and when not transmitting.

3.1.80 transport stream: In MPEG-2, a packet based method of multiplexing one or more digital video and audio streams having one or more independent time bases into a single stream.

3.1.81 trivial file transfer protocol (TFTP): An Internet protocol for transferring files without the requirement for user names and passwords that is typically used for automatic downloads of data and software.

3.1.82 type/length/value (TLV): An encoding of three fields, in which the first field indicates the type of element, the second the length of the element, and the third field the value.

3.1.83 upstream: The direction from the subscriber location toward the BTS.

3.2 Abbreviations

This Recommendation uses the following abbreviations:

AAL5	ATM Adaptation Layer 5
ANSI	American National Standards Institute
ARP	Address Resolution Protocol
ATM	Asynchronous Transfer Mode
BC	Broadcast Channel
BIM	Broadcast Interface Module
BPDU	Bridge Protocol Data Unit
BRA	Basic Rate Access
BTS	Base Transceiver Station. A BTS could contain multiple BTS modems
BW	BandWidth
BWA	Broadband Wireless Access
CATV	Cable Television
CATV	Community Antenna TeleVision (System)
CM	Cable Modem, IIM, MH
CMCI	Cable Modem to CPE Interface
CMTS	Cable Modem Termination System
CMTS-NSI	Cable Modem Termination System – Network Side Interface
C/N (or CNR)	Carrier-to-Noise Ratio
CPE	Customer Premises Equipment
CRC	Cyclic Redundancy Check
CSO	Composite Second Order beat

CTB	Composite Triple Beat
DA	Destination Address
DAVIC	Digital AudioVIsual Council
DCE	Data Communication Equipment
DHCP	Dynamic Host Configuration Protocol
DL	Data Link
DOBSS	Data over BWA Security System
DOC	Data over Cable
DTE	Data Terminal Equipment
DTMF	Dual Tone Multifrequency (dialling mode)
DVB	Digital Video Broadcasting
DVB-MS	DVB – Microwave Satellite
EH or EHDR	Extended Header
EIA	Electronic Industries Alliance
FAS	Frame Alignment Signal
FC	Frame Control
FDDI	Fibre Distributed Data Interface
FDM	Frequency Division Multiplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FIFO	First In First Out
FIP	Forward Interaction Path
FSR	Linear Feedback Shift Register
FWA	Fixed Wireless Access
GSTN	General Switched Telephone Network
GT	Global Time
HCS	Header Check Sequence
HF	High Frequency
HFC	Hybrid Fibre/Coax system
HRC	Harmonic Related Carrier
IB	In-Band
IC	Interaction Channel
ICMP	Internet Control Message Protocol
ID	IDentifier
IE	Information Element
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

IETF	Internet Engineering Task Force
IF	Intermediate Frequency
IIM	Interactive Interface Module
INA	Interactive Network Adapter
IP	Internet Protocol
IQ	In-phase and Quadrature Components
IRC	Incremental Related Carriers
IRD	Integrated Receiver Decoder
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
LAN	Local Area Network
LEN	Length (in bytes unless otherwise stated)
LFSR	Linear Feedback Shift Register
LLC	Logical Link Control procedure
LMCS	Local Multipoint Communication System
LMDS	Local Multipoint Distribution System
LSB	Least Significant Bit
LT	Local time
MAC	Media Access Control
MC	Multimedia Centre Equipment
MCNS	Multimedia Cable Network System
MH	Multimedia Home equipment
MMDS	Multichannel Multipoint Distribution Systems
MPEG	Moving Picture Experts Group
MS	Microwave Satellite
MSAP	MAC Service Access Point
MSB	Most Significant Bit
MTTR	Mean Time to Repair
NCTA	National Cable Television Association
NIU	Network Interface Unit
NSAP	Network Service Access Point
NTSC	National Television Systems Committee
OH	OverHead
OOB	Out of Band
OSI	Open Systems Interconnection
OUI	Organisation Unique Identifier
PHY	Physical layer

PID	Packet Identifier
PM	Phase Modulation
PM	Pulse Modulation
PMD	Physical Media Dependent sublayer
PSI	Program Specific Information
PSK	Phase Shift Keying
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quaternary Phase-Shift Keying
REQ	Request indicator used in Annex B
RF	Radio Frequency
RFC	Request for Comments
RIP	Return Interaction Path
RMS	Root Mean Square
RNG	Ranging
RS	Reed Solomon
RTD	Round Trip Delay
SAP	Service Access Point
SDU	Service Data Unit
SID	Service Identifier
SL-ESF	Signalling Link Extended Superframe
SMATV	Satellite Master Antenna Television
SMS	Spectrum Management System
SNAP	Subnetwork Access Protocol
SNMP	Simple Network Management Protocol
STB	Set Top Box
STU	Set Top Unit
SYNC	Synchronisation
TC	Transmission Convergence sublayer
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TFTP	Trivial File Transfer Protocol
TLV	Type/Length/Value
TS	Transport Stream

UCC	Upstream Channel Change
UCD	Upstream Channel Descriptor
VCI	Virtual Channel Identifier

ANNEX A

Interaction channel for local multipoint distribution systems

(based on ITU-T Recommendation J.112, Annex A)

A.1 Scope

This annex is derived from European Norm EN 301 199 (and also based on ITU-T J.112, Annex A) for the provision of an interaction channel for Local Multipoint Distribution Systems (LMDS) networks.

A.2 References

See the common part of this Recommendation.

A.3 Terms, definitions and acronyms

See clause 3.

A.4 Reference model

This clause presents the reference model for system architecture of narrow-band interaction channels in a broadcasting scenario (asymmetric interactive services).

A.4.1 Protocol stack model

For asymmetric interactive services supporting broadcast to the home with narrow-band return channel, a simple communications model consists of the following layers:

– **Physical layer**: where all the physical (electrical) transmission parameters are defined.
– **Transport layer**: defines all the relevant data structures and communication protocols like data containers, etc.
– **Application layer**: is the interactive application software and runtime environments (e.g. home shopping application, script interpreter, etc.).

This annex addresses the lower two layers (the physical and transport) leaving the application layer open to competitive market forces.

A simplified model of the OSI layers was adopted to facilitate the production of specifications for these nodes. Figure A.1 points out the lower layers of the simplified model and identifies some of the key parameters for the lower two layers. Following the user requirements for interactive services, no attempt will be made to consider higher layers in this annex.

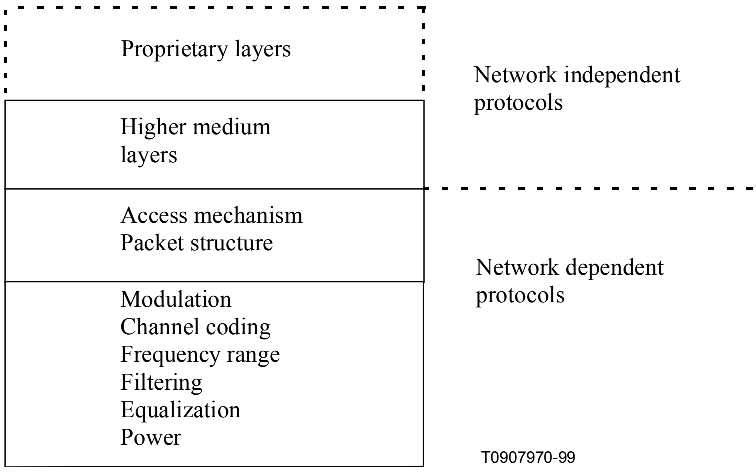


Figure A.1/J.116 – Layer structure for generic system reference model

This annex addresses the PSTN/ISDN network specific aspects only. The network independent protocols will be specified separately.

A.4.2 System model

Figures A.2a and A.2b show the system model which is to be used within DVB for interactive services.

In the system model, two channels are established between the service provider and the user:

– **Broadcast Channel (BC)**: a unidirectional broadband BC including video, audio and data. BC is established from the service provider to the users. It may include the Forward Interaction path.

– **Interaction channel**: a bidirectional interaction channel is established between the service provider and the user for interaction purposes. It is formed by:

  • Return **interaction path (return channel)**: from the user to the service provider. It is used to make requests to the service provider or to answer questions. It is a narrow-band channel. Also commonly known as return channel.

  • Forward **interaction path**: from the service provider to the user. It is used to provide some sort of information by the service provider to the user and any other required communication for the interactive service provision. It may be embedded into the BC. It is possible that this channel is not required in some simple implementations which make use of the BC for the carriage of data to the user.

The user terminal is formed by the Network Interface Unit (NIU) (consisting of the Broadcast Interface Module (BIM) and the Interactive Interface Module (IIM)) and the Set Top Unit (STU). The user terminal provides interface for both broadcast and interaction channels. The interface between the user terminal and the interaction network is via the IIM.

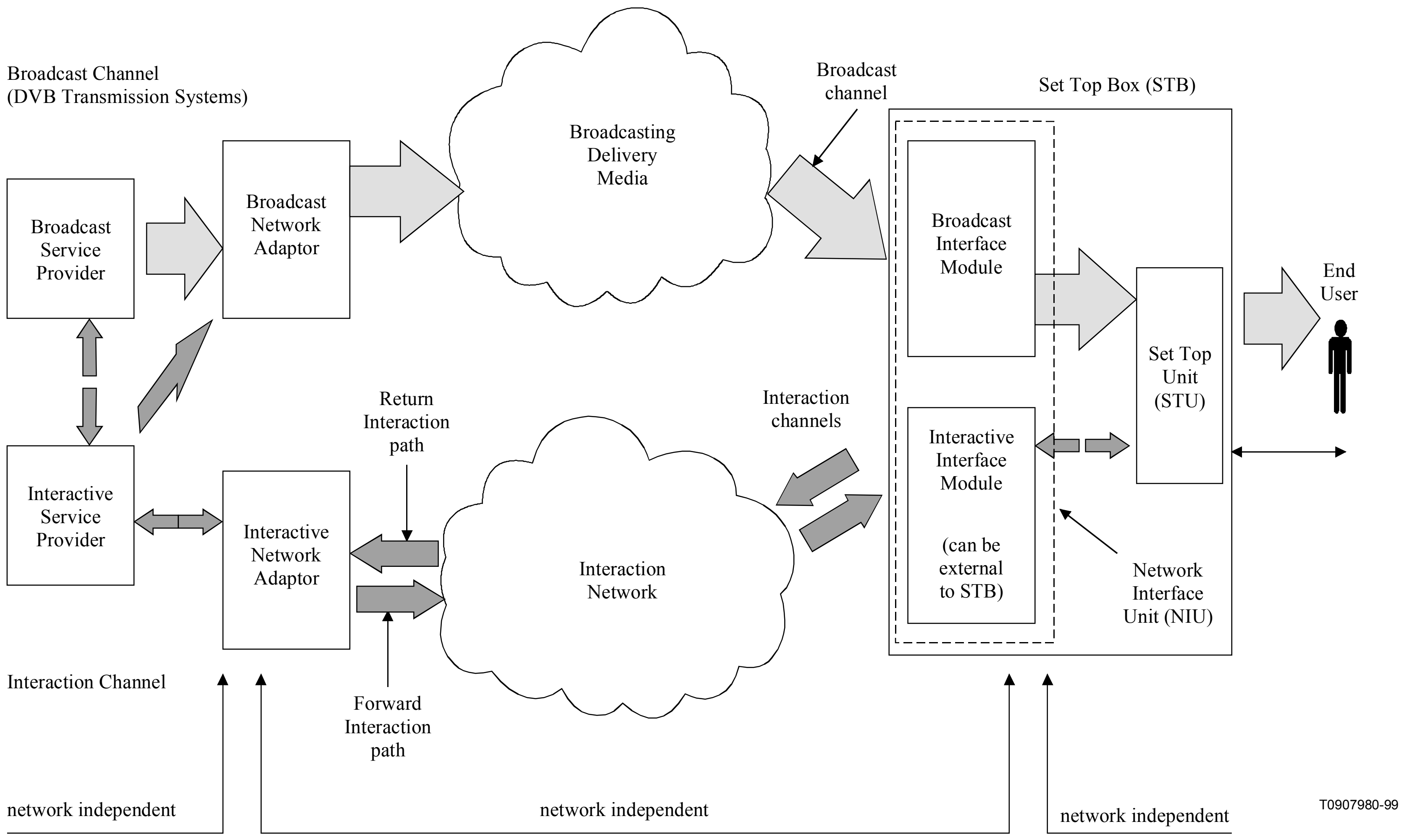


Figure A.2a/J.116 – Generic system reference model for interactive systems

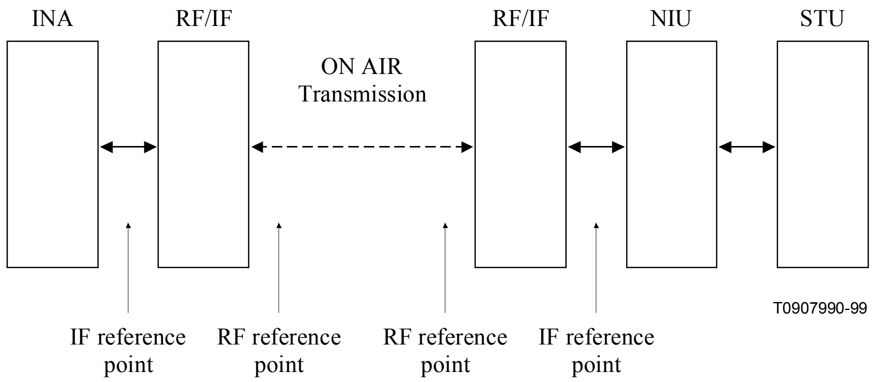


Figure A.2b/J.116 – Position of IF and RF reference points in the particular case of LMDS networks

A.5 Interaction channel specification for LMDS networks

The LMDS infrastructures can support the implementation of the return channel for interactive services suitable for DVB broadcasting systems.

LMDS can be used to implement interactive services in the DVB environment, providing a bidirectional communication path between the user terminal and the service provider.

A.5.1 System concept

The interactive system is composed of Forward Interaction path (downstream) and Return Interaction path (upstream). The general concept is to use downstream transmission from the INA to the NIU's to provide synchronisation and information to all NIUs. This allows the NIUs to adapt to the network and send synchronised information upstream. See Figure A.2b.

Upstream transmission is divided into time slots which can be used by different users, using the technique of Time Division Multiple Access (TDMA). One downstream channel is used to synchronise up to eight upstream channels, which are all divided into time slots. A counter at the INA is sent periodically to the NIUs, so that all NIUs work with the same clock. This gives the opportunity to the INA to assign time slots to different users.

Three major access modes are provided with this system. The first one is based on contention access, which lets users send information at any time with the risk to have a collision with other users' transmissions. The second and third modes are contentionless based, where the INA either provides a finite amount of slots to a specific NIU, or a given bit rate requested by a NIU until the INA stops the connection on NIU's demand. These access modes are dynamically shared among time slots, which allows NIUs to know when contention based transmission is or is not allowed. This is to avoid a collision for the two contentionless based access modes.

Periodically, the INA will indicate to new users that they have the possibility to go through Sign-On procedure, in order to give them the opportunity to synchronise their clock to the network clock, without risking collisions with already active users. This is done by leaving a larger time interval for new users to send their information, taking into account the propagation time required from the INA to the NIUs and back.

A.5.1.1 Out-of-Band (OOB)/In-Band (IB) principle

This interactive system is based either on OOB or IB downstream signalling. However, STBs do not need to support both systems.

In the case of OOB signalling, a Forward Interaction path is added. This path is reserved for interactivity data and control information only. The presence of this added Forward Information path is in that case mandatory. However, it is also possible to send higher bit rate downstream information through a DVB-MS channel whose frequency is indicated in the forward information path.

In the case of IB signalling, the Forward Information path is embedded into the MPEG2-TS of a DVB-MS channel. It is not mandatory to include the Forward Information path in all DVB-MS channels.

Both systems can provide the same quality of service. However, the overall system architecture will differ between networks using IB and OOB STBs. Both types of systems may exist on the same networks under the condition that different frequencies are used for each system.

A.5.1.2 Intermediate Frequency (IF) spectrum allocation

The Radio Frequency (RF) spectrum allocation is still to be defined and allocated by the regulatory bodies. The following IF ranges to use are not mandatory:

– For downstream, both IB and OOB channels can use the 950 MHz to 2150 MHz band.

– For upstream channels two different choices can be identified:

  1) For the OOB signalling, in order to keep compatibility with equipment used in existing cable networks in accordance with the J.112 Annex A, the bands 70 MHz to 130 MHz and 5 MHz to 65 MHz can be used for downstream and upstream respectively.

  2) For the IB signalling, taking into account the backward compatibility with the cable specifications and in order to give major capacity for the future interactive and multimedia services, the frequency allocation is 5 MHz to 305 MHz.

See Figures A.3a and A.3b.

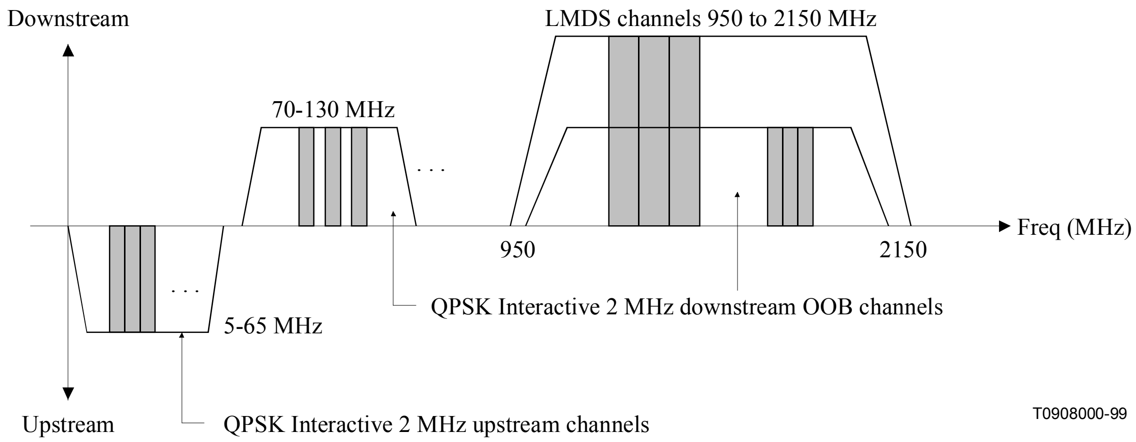


Figure A.3a/J.116 – Preferred IF frequency ranges for LMDS interactive systems (OOB)

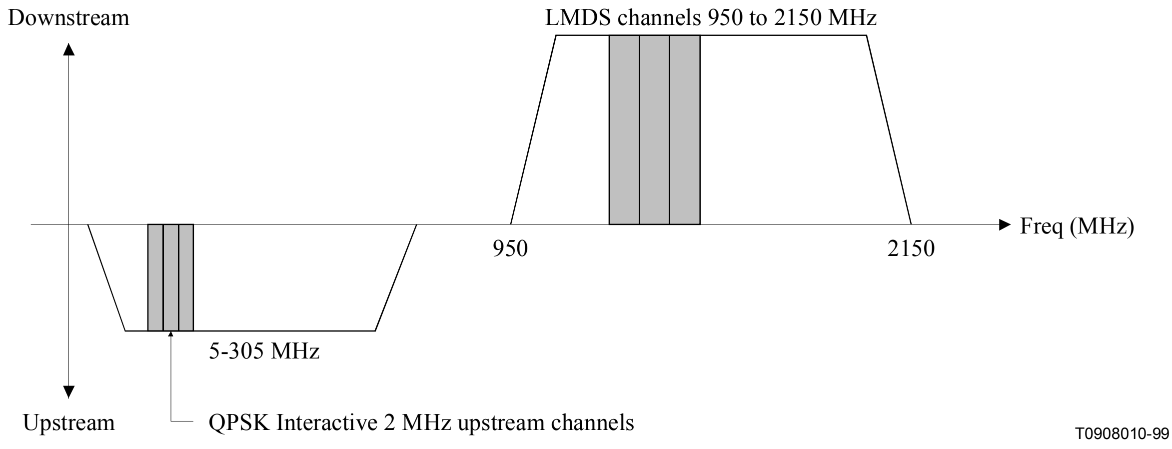


Figure A.3b/J.116 – Preferred IF frequency ranges for LMDS interactive systems (IB)

A.5.1.3 FDM/TDMA multiple access

A multiple access scheme is defined in order to have different users share the same transmission media. Downstream information is sent broadcast to all users of the networks. Thus, an address assignment exists for each user which allows the INA to send information singlecast to one particular user. Two addresses are stored in STBs in order to identify users on the network:

– MAC address: It is a 48-bit value representing the unique MAC address of the NIU. This MAC address may be hard coded in the NIU or be provided by external source.

– NSAP address: It is a 160-bit value representing a network address. This address is provided by higher layers during communication.

Upstream information may come from any user in the network and shall therefore also be differentiated at the INA using the set of addresses defined above.

Upstream and OOB downstream channels are divided into separate channels of 2 MHz bandwidth for downstream and upstream. Each downstream channel contains a synchronisation frame used by up to eight different upstream channels, whose frequencies are indicated by the MAC protocol.

Within upstream channels, users send packets with TDMA type access. This means that each channel is shared by many different users, who can either send packets with a possibility of collisions when this is allowed by the INA, or request transmission and use the packets assigned by the INA to each user specifically. Assuming each channel can therefore accommodate thousands of users at the same time, the upstream bandwidth can easily be used by all users present on the network at the same time.

The TDMA technique uses a slotting method which allows the transmit start times to be synchronised to a common clock source. Synchronising the start times increases message throughput of this signalling channel since the message packets do not overlap during transmission. The period between sequential start times are identified as slots. Each slot is a point in time when a message packet can be transmitted over the signalling link.

The time reference for slot location is received via the downstream channels generated at the delivery system and received simultaneously by all STUs. This time reference is not sent in the same way for OOB and IB signalling. Since all NIUs reference the same time base, the slot times are aligned for all NIUs. However, since there is propagation delay in any transmission network, a time base ranging method accommodates deviation of transmission due to propagation delay.

Since the TDMA signalling link is used by NIUs that are engaged in interactive sessions, the number of available message slots on this channel is dependent on the number of simultaneous users. When messaging slots are not in use, an NIU may be assigned multiple message slots for increased messaging throughput. Additional slot assignments are provided to the NIU from the downstream signalling information flow.

There are different access modes for the upstream slots:

– reserved slots with fixed rate reservation (fixed rate access: the user has a reservation of one or several time slots in each frame enabling, e.g. for voice, audio);

– reserved slots with dynamic reservation (reservation access: the user sends control information announcing his demand for transmission capacity. He gets grants for the use of slots);

– contention based slots (these slots are accessible for every user. Collision is possible and solved by a contention resolution protocol);

– ranging slots (these slots are used upstream to measure and adjust the time delay and the power).

These slots may be mixed on a single carrier to enable different services on one carrier only. If one carrier is assigned to one specific service, only those slot types will be used which are needed for this service. Therefore a terminal can be simplified to respond to only those slot types assigned to the service.

A.5.1.4 Bit rates and framing

For the interactive downstream OOB channel, a rate of 3.088 Mbit/s may be used. For downstream IB channels, no other constraints than those specified in the DVB-MS specifications exist, but a guideline would be to use rates multiples of 8 kbit/s.

Downstream OOB channels continuously transmit a frame based on T1 type framing, in which some information is provided for synchronisation of upstream slots. Downstream IB channels transmit some MPEG2-TS packets with a specific PID for synchronisation of upstream slots (at least one packet containing synchronisation information shall be sent in every period of 3 ms).

Upstream framing consists of packets of 512 bits (256 symbols) which are sent in a bursty mode from the different users present on the network. The upstream slot rates are 6000 upstream slots/s.

A.5.2 Lower physical layer specification

In this clause, detailed information is given on the lower physical layer specification. Figures A.4 and A.5 show the conceptual block diagrams for implementation of this specification.

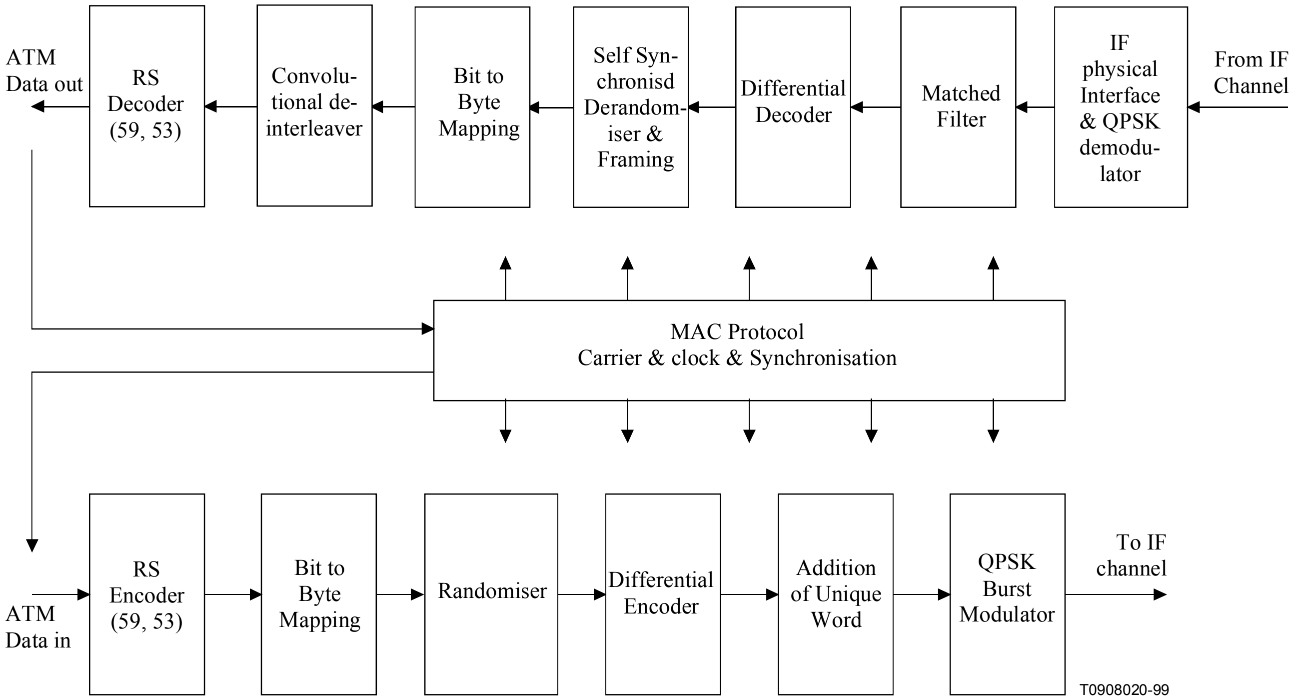


Figure A.4/J.116 – Conceptual block diagram for the NIU OOB transceiver

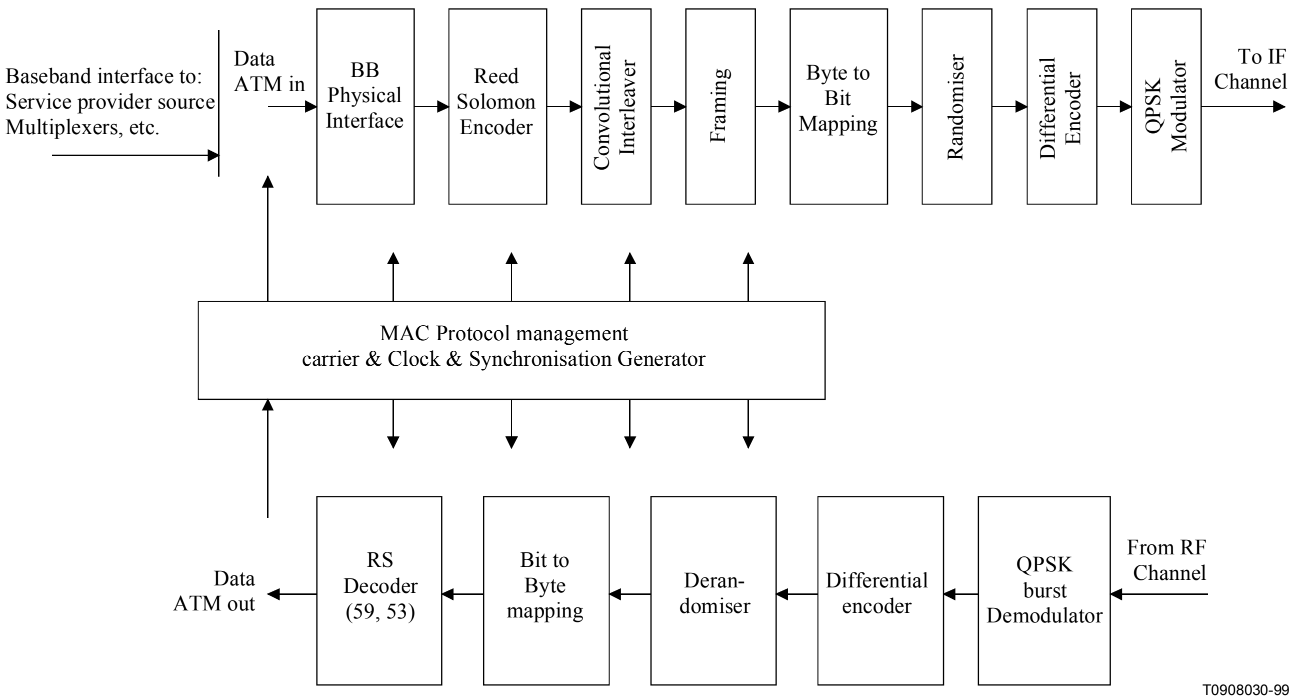


Figure A.5/J.116 – Conceptual block diagram for the OOB head-end transceiver

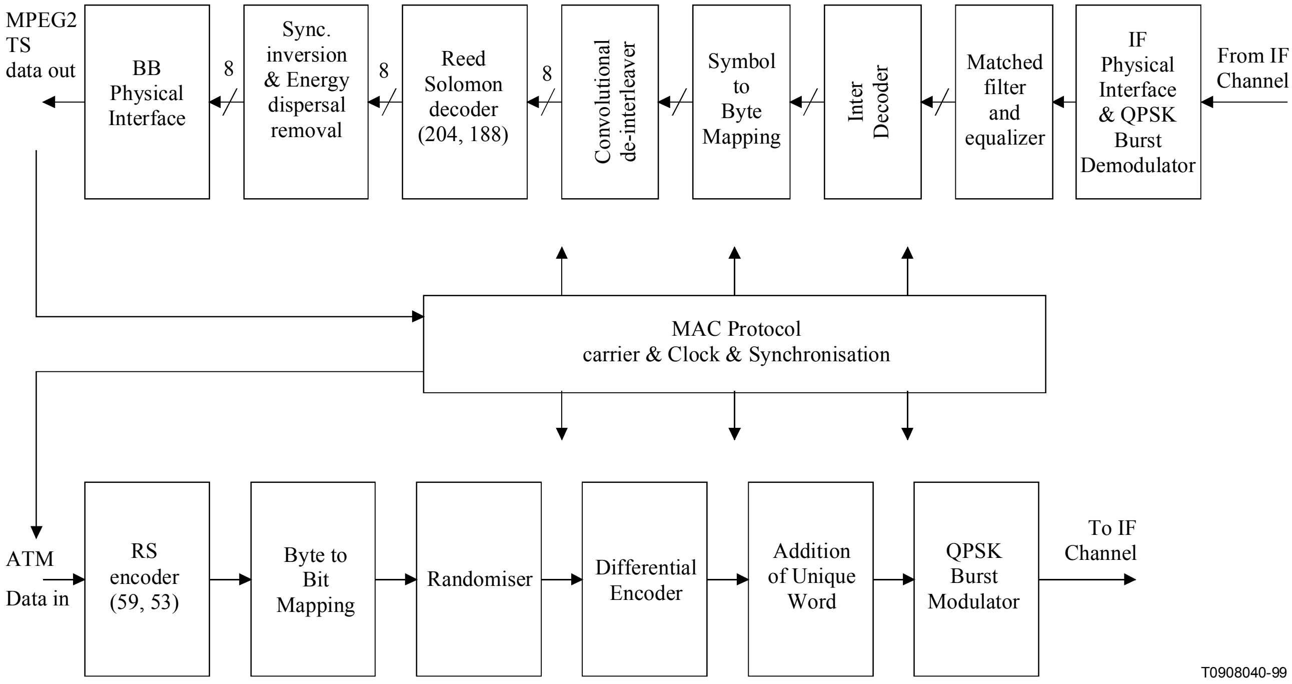


Figure A.6/J.116 – Conceptual block diagram for the IB NIU transceiver

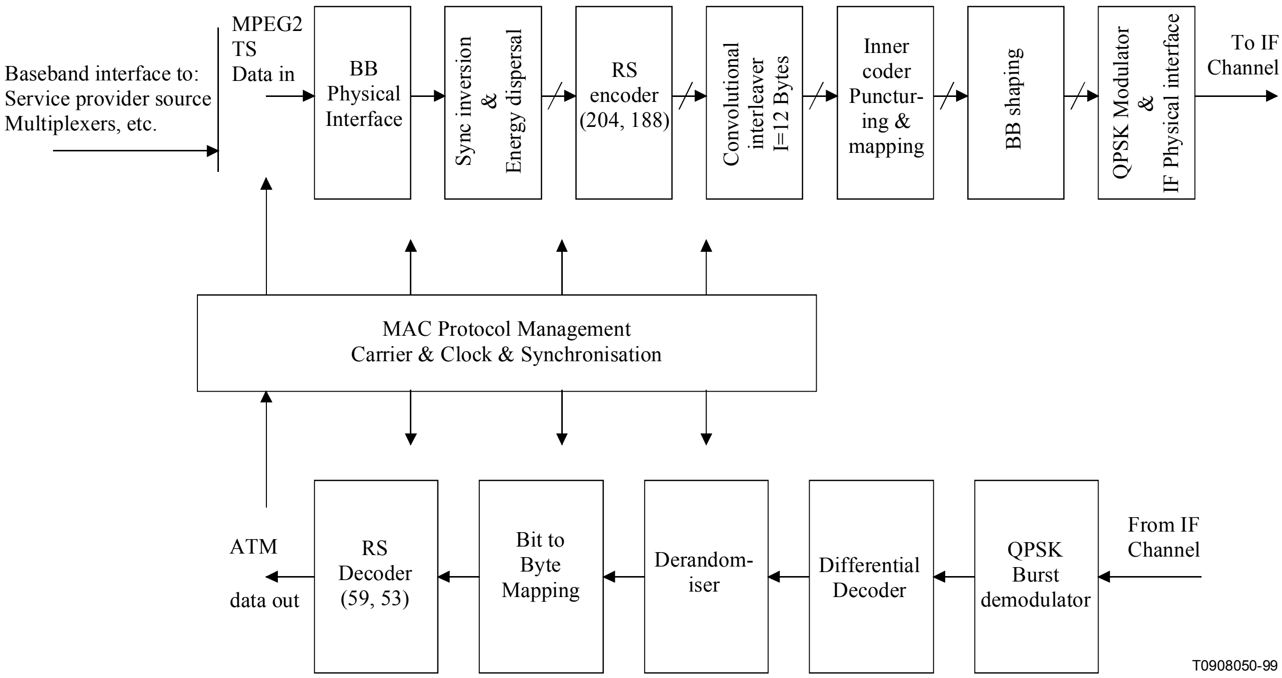


Figure A.7/J.116 – Conceptual block diagram for the IB head-end transceiver

A.5.2.1 Forward Interaction path (downstream OOB)

A.5.2.1.1 Frequency range (downstream OOB)

See A.5.1.2.

A.5.2.1.2 Modulation and mapping (downstream OOB)

QPSK modulation is used as a means of encoding digital information over wireless or wireline transmission links. The method is a subset of Phase Shift Keying (PSK) which is a subset of Phase Modulation (PM). Specifically QPSK is a four-level use of digital PM. Quadrature signal representations involve expressing an arbitrary phase sinusoidal waveform as a linear combination of a cosine wave and a sine wave with zero starting phases.

QPSK systems require the use of differential encoding and corresponding differential detection. This is a result of the receivers having no method of determining if a recovered reference is a sine reference or a cosine reference. In addition, the polarity of the recovered reference is uncertain.

Differential encoding transmits the information in encoded phase differences between the two successive signals.

The modulator processes the digital binary symbols to achieve differential encoding and then transmits the absolute phases.

The differential encoding is implemented at the digital level.

The differential encoder shall accept bits A, B in sequence, and generate phase changes as follows (see Table A.1):

Table A.1/J.116 – Phase changes associated with bit A, B

A	B	Phase Change
0	0	None
0	1	+90°
1	1	180°
1	0	–90°

In serial mode, A arrives first. The outputs I, Q from the differential encoder map to the phase states as in Figure A.8.

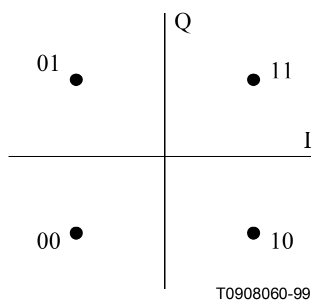


Figure A.8/J.116 – Mapping for the QPSK constellation (downstream OOB)

The phase changes can also be expressed by the following formulae (assuming the constellation is mapped from I and Q as shown in subclause A.5.2.3.2):

$$\begin{cases} A_k = \overline{(I_{k-1} \oplus Q_{k-1})} \times (Q_{k-1} \oplus Q_k) + \overline{(I_k \oplus Q_{k-1})} \times (I_k \oplus I_{k-1}) \\ B_k = \overline{(I_{k-1} \oplus Q_{k-1})} \times (I_{k-1} \oplus I_k) + \overline{(I_{k-1} \oplus Q_k)} \times (Q_k \oplus Q_{k-1}) \end{cases}$$

where k is the time index.

I/Q amplitude imbalance shall be less than 1.0 dB, and phase imbalance less than 2.0º.

A.5.2.1.3 Shaping filter (downstream OOB)

The time-domain response of a square-root raised-cosine pulse with excess bandwidth parameter α is given by:

$$g(t) = \frac{\sin\left[\frac{\pi t}{T}(1-\alpha)\right] + \frac{4\alpha t}{T}\cos\left[\frac{\pi t}{T}(1+\alpha)\right]}{\frac{\pi t}{T}\left[1-\left(\frac{4\alpha t}{T}\right)^2\right]}$$

where T is the symbol period.

The output signal shall be defined as:

$$S(t) = \sum_n \left[I_n \times g(t-nT) \times \cos(2\pi f_c t) - Q_n \times g(t-nT) \times \sin(2\pi f_c t)\right]$$

with I_n and Q_n equal to ±1, independently from each other, and f_c the QPSK modulator's carrier frequency.

The QPSK modulator divides the incoming bit stream so that bits are sent alternately to the in-phase modulator I and the out-of-phase modulator Q. These same bit streams appear at the output of the respective phase detectors in the demodulator where they are interleaved back into a serial bit stream.

The occupied bandwidth of a QPSK signal is given by the equation:

$$\text{Bandwidth} = \frac{f_b}{2}\ (1 + \alpha)$$

f_b = bit rate

α = excess bandwidth = 0.30

The spectral mask is the following (see Table A.2):

Table A.2/J.116 – Spectral mask for QPSK modulated signal

BW (MHz)	Response (dB)
1	0 ± 0.25
1.544	−3 ± 0.25
2.0	−24 ± 3
2.16	< −36
3.08	< −40
3.6	< −50

Carrier suppression shall be greater than 30 dB.

A.5.2.1.4 Randomiser (downstream OOB)

After addition of the Forward Error Correction (FEC) bytes (see A.5.3), all of the 3.088 Mbit/s data is passed through a six register Linear Feedback Shift Register (LFSR) randomiser to ensure a random distribution of ones and zeroes.

The generating polynomial is:

$$x^6 + x^5 + 1$$

Byte/serial conversion shall be MSB first. A complementary self-synchronising de-randomiser is used in the receiver to recover the data. See Figures A.9 and A.10.

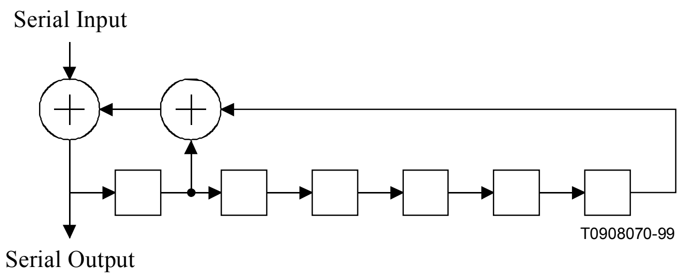


Figure A.9/J.116 – Randomiser

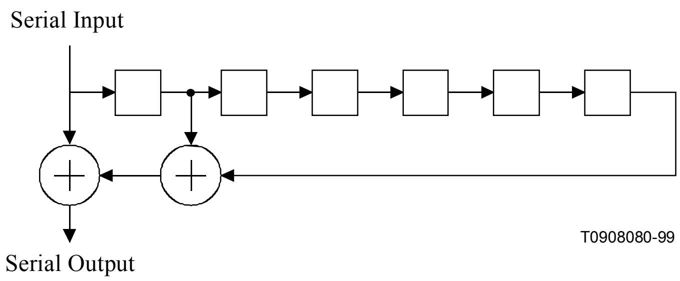


Figure A.10/J.116 – De-randomiser

A.5.2.1.5 Bit rate (downstream OOB)

The bit rate shall be 3.088 Mbit/s. Symbol rate accuracy should be within ±50 ppm.

A.5.2.1.6 Receiver power level (downstream OOB)

The receiver power level shall be in the range 42 dBμV to 75 dBμV (RMS) (75 Ω) at the IF input point.

A.5.2.1.7 Summary (downstream OOB)

See Table A.3.

Table A.3/J.116 – Summary (downstream)

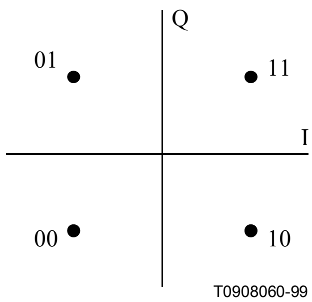
Summary (downstream)	
Transmission rate	3.088 Mbit/s
Modulation	Differentially encoded QPSK.
Transmit filtering	Filtering is $\alpha = 0.30$ square root raised cosine
Channel spacing	2 MHz
Frequency step size	250 kHz (centre frequency granularity)
Randomisation	After addition of the FEC bytes, all of the 3.088 Mbit/s data is passed through a six register Linear Feedback Shift Register (LFSR) randomiser to ensure a random distribution of ones and zeroes. The generating polynomial is: $x^6 + x^5 + 1$. Byte/serial conversion shall be MSB first. A complementary self-synchronising de-randomiser is used in the receiver to recover the data.
Differential encoding	The differential encoder shall accept bits A, B in sequence, and generate phase changes as follows: A B Phase change 0 0 none 0 1 +90° 1 1 180° 1 0 −90° In serial mode, A arrives first.
System phase noise max.: (phase noise includes both IF and RF parts).	–41 dBc/Hz at 1 kHz –71 dBc/Hz at 10 kHz –92 dBc/Hz at 100 kHz
Signal constellation	The outputs I, Q from the differential encoder map to the phase states as in Figure A.11.  **Figure A.11/J.116**
IF range (not mandatory)	950-2150 MHz or 70-130 MHz
Frequency stability	±50 ppm measured at the upper limit of the IF range
Symbol rate accuracy	±50 ppm

Table A.3/J.116 – Summary (downstream) ***(continued)***

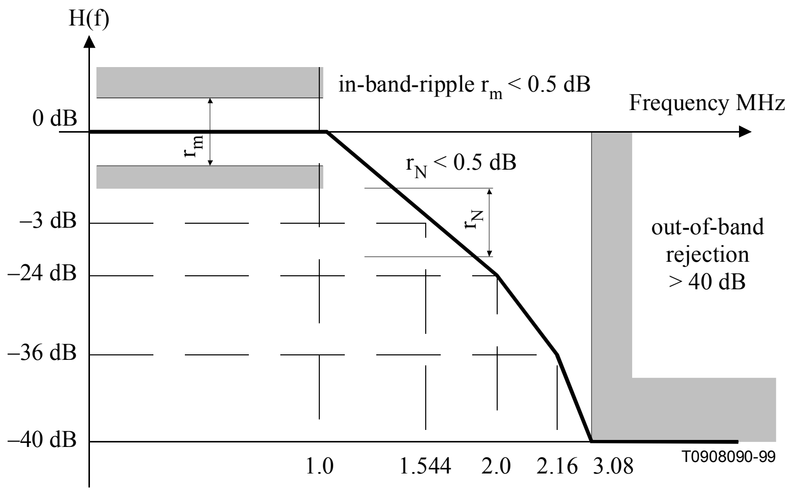
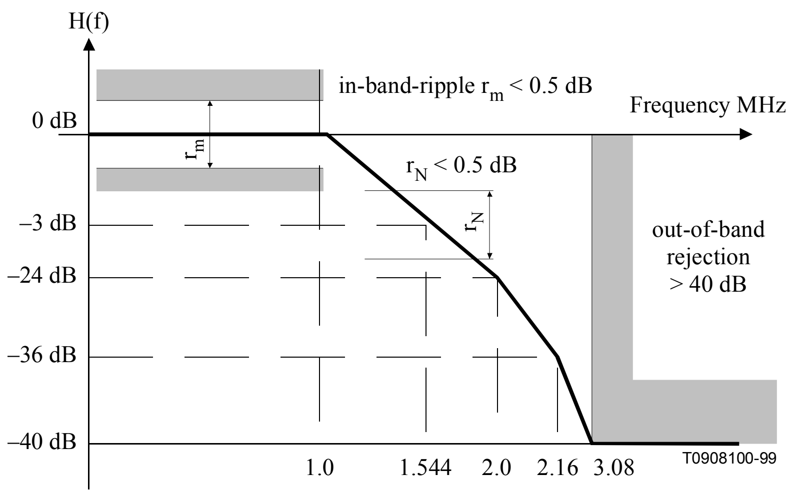
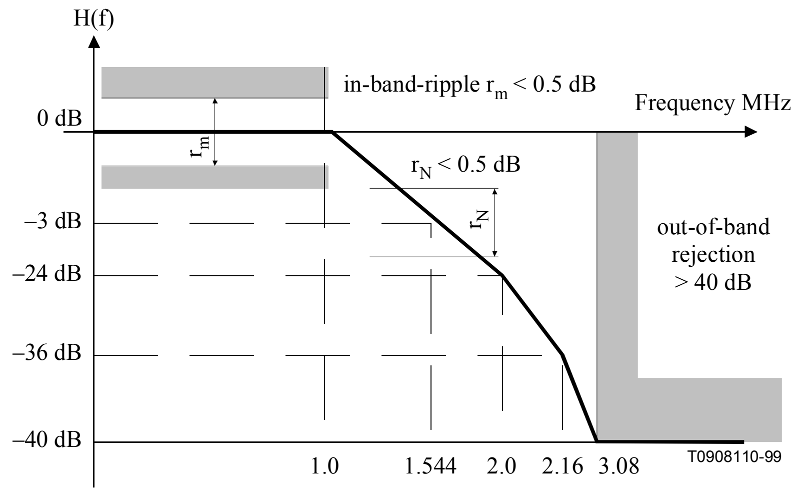
Summary (downstream)	
Carrier suppression	>30 dB
I/Q amplitude imbalance	<1.0 dB
I/Q phase imbalance	<2.0º
Receive power level at IF reference point (downstream out-of-band)	42-75 dBµV (RMS) (75 Ω)
Transmit spectral mask	Bit rate = 3.088 Mbit/s BW (MHz) – Response (dB) 1.0 – 0 ± 0.25 1.544 – −3 ± 0.25 2.0 – < −24 ± 3 2.16 – < −36 3.088 – < −40  

Table A.3/J.116 – Summary (downstream) ***(concluded)***

Summary (downstream)	
	

A.5.2.1.8 Bit error rate downstream OOB (informative)

For further study.

A.5.2.2 Forward Interaction path (downstream IB)

The IB Forward Interaction path shall use a MPEG2-TS stream with a modulated QPSK channel as defined in Annex A/J.83. Frequency range, channel spacing, and other lower physical layer parameters should follow Annex A/J.83.

A.5.2.3 Return Interaction path (upstream)

A.5.2.3.1 IF range (upstream)

The frequency range is not specified as mandatory although a guideline is provided to use the 5 to 65 MHz range. Frequency stability shall be in the range ±50 ppm measured at the upper limit of the frequency range.

A.5.2.3.2 Modulation and mapping (upstream)

The unique word 0x 00 FC FC F3, (see A.5.3 for upstream framing) is not differentially encoded. The outputs I, Q map to the phase states as in Figure A.12.

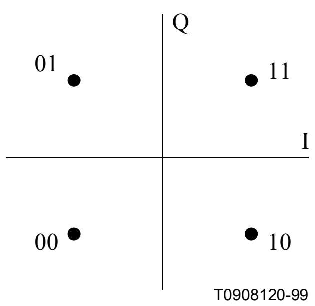


Figure A.12/J.116 – Mapping for the QPSK constellation (upstream)

For the remainder of the packet, the differential encoder shall accept bits A, B in sequence, and generate phase changes as follows. It starts with the first information digit and is initialised with the last digit of the unique word, i.e. (A, B = 1, 1) since conversion is made MSB first. See Table A.4.

Table A.4/J.116 – Phase changes corresponding to bits A, B

A	B	Phase Change
0	0	None
0	1	+90°
1	1	180°
1	0	−90°

Phase changes correspond to the following formulae (assuming I and Q are mapped to the constellation as for the unique word):

$$\begin{cases} A_k = \overline{(I_{k-1} \oplus Q_{k-1})} \times (Q_{k-1} \oplus Q_k) + \overline{(I_k \oplus Q_{k-1})} \times (I_k \oplus I_{k-1}) \\ B_k = \overline{(I_{k-1} \oplus Q_{k-1})} \times (I_{k-1} \oplus I_k) + \overline{(I_{k-1} \oplus Q_k)} \times (Q_k \oplus Q_{k-1}) \end{cases}$$

where k is the time index.

I/Q amplitude imbalance shall be less than 1.0 dB, and phase imbalance less than 2.0º.

A.5.2.3.3 Shaping filter (upstream)

The time-domain response of a square-root raised-cosine pulse with excess bandwidth parameter α is given by:

$$g(t) = \frac{\sin\left[\frac{\pi t}{T}(1-\alpha)\right] + \frac{4\alpha t}{T}\cos\left[\frac{\pi t}{T}(1+\alpha)\right]}{\frac{\pi t}{T}\left[1-\left(\frac{4\alpha t}{T}\right)^2\right]}$$

where T is the symbol period.

The output signal shall be defined as:

$$S(t) = \sum_n \left[I_n \times g(t-nT) \times \cos(2\pi f_c t) - Q_n \times g(t-nT) \times \sin(2\pi f_c t)\right]$$

with I_n and Q_n equal to ±1, independently from each other, and f_c the QPSK modulator's carrier frequency.

The QPSK modulator divides the incoming bit stream so that bits are sent alternately to the in-phase modulator I and the out-of-phase modulator Q. These same bit streams appear at the output of the respective phase detectors in the demodulator where they are interleaved back into a serial bit stream.

The occupied bandwidth of a QPSK signal is given by the equation:

$$\text{Bandwidth} = \frac{f_b}{2}(1+\alpha)$$

f_b = bit rate

α = excess bandwidth = 0.30

The spectral mask is given in Table A.5.

Table A.5/J.116 – Spectral mask for bit rate = 3.088 Mbit/s

BW (MHz)	Response (dB)
1.0	0 ± 0.25
1.544	−3 ± 0.25
2.0	−24 ± 3
2.16	< −36
3.088	< −40
3.6	< −50

Carrier suppression shall be greater than 30 dB.

A.5.2.3.4 Randomiser (upstream)

The unique word shall be sent in clear (see A.5.3). After addition of the FEC bytes, randomisation shall apply only to the payload area and FEC bytes, with the randomiser performing modulo 2 addition of the data with a pseudo-random sequence. The generating polynomial is $x^6 + x^5 + 1$ with seed all ones. It is assumed that the first value coming out of the pseudo-random generator taken into account is 0. Byte/serial conversion shall be MSB first. The binary sequence generated by the shift register starts with 00000100...... The first "0" is to be added in the first bit after the unique word.

A complementary non self-synchronising de-randomiser is used in the receiver to recover the data. The de-randomiser shall be enabled after detection of the unique word. See Figure A.13.

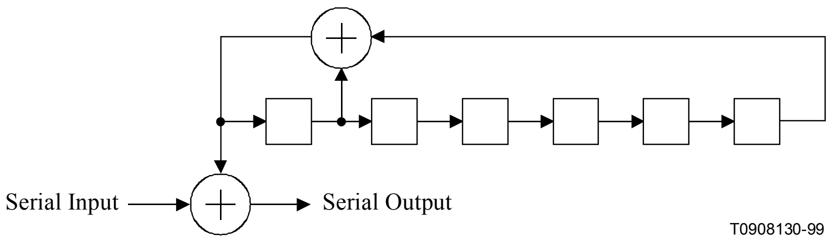


Figure A.13/J.116 – Randomiser

A.5.2.3.5 Bit rate (upstream)

The upstream bit rate is 3.088 Mbit/s, which corresponds to 6000 slots/s.

Symbol rate accuracy should be within ±50 ppm.

A.5.2.3.6 Transmit power level (upstream)

At the IF output the transmit power level shall be in the range 85 dBµV to 113 dBµV (RMS) (75 Ω). This power shall be adjusted by steps of 0.5 dB by MAC messages coming from the INA.

A.5.2.3.7 Carrier suppression when idle (upstream)

The carrier suppression shall be more than 60 dB below nominal power output level, over the entire power output range.

A terminal is considered to be idle if it is three slots before an imminent transmission or three slots after its most recent transmission.

A.5.2.3.8 Summary (upstream)

See Table A.6.

Table A.6/J.116 – Summary (upstream)

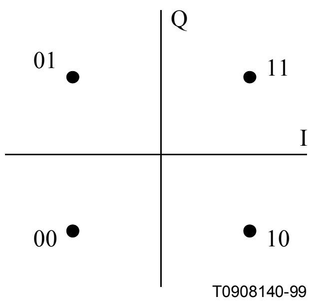
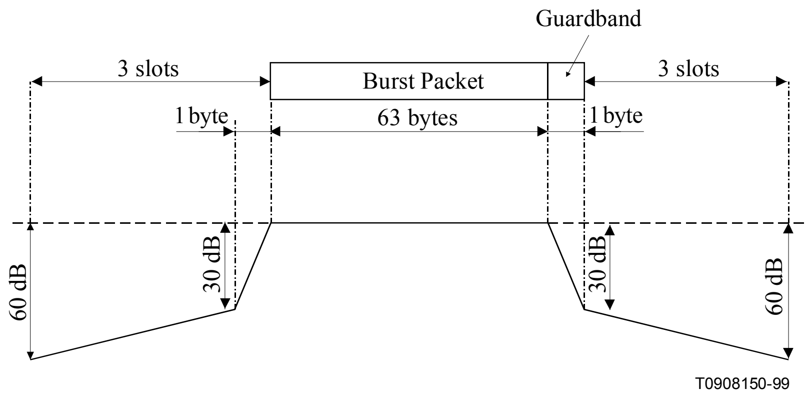
Summary (upstream)	
Transmission rate	3.088 Mbit/s
System phase noise max.:	−41 dBc/Hz at 1 kHz −71 dBc/Hz at 10 kHz −92 dBc/Hz at 100 kHz
Modulation	Differentially encoded QPSK
Transmit filtering	α = 0.30 square root raised cosine
Channel spacing	2 MHz
Frequency step size	50 kHz
Randomisation	The unique word shall be sent in the clear. After addition of the FEC bytes, randomisation shall apply only to the payload area and FEC bytes, with the randomiser performing modulo 2 addition of the data with a pseudo-random sequence. The generating polynomial is $x^6 + x^5 + 1$ with seed all ones. Byte/serial conversion shall be MSB first. A complementary non self-synchronising de-randomiser is used in the receiver to recover the data. The de-randomiser shall be enabled after detection of the unique word.
Differential encoding	The differential encoder shall accept bits A, B in sequence, and generate phase changes as follows. In serial mode, A arrives first. A B Phase change 0 0 none 0 1 +90° 1 1 180° 1 0 −90°
Signal constellation NOTE – The unique word (Ox 00 FC FC F3) does not go through differential encoding.	The outputs I, Q from the differential encoder map to the phase states as in Figure A.14.  **Figure A.14/J.116**

Table A.6/J.116 – Summary (upstream) ***(concluded)***

Summary (upstream)	
Frequency range (informative)	5-65 MHz or 5-305 MHz
Frequency stability	±50 ppm measured at the upper limit of the IF range
Symbol rate accuracy	±50 ppm
Transmit spectral mask	Bit rate = 3.088 Mbit/s BW (MHz) Response (dB) 1.0 0 ± 0.25 1.54 −3 ± 0.25 2.0 −24 ± 3 2.16 < −36 2.54 < −40
Carrier suppression when transmitter active	>30 dB
Carrier suppression when transmitter idle	The carrier suppression shall be more than 60 dB below nominal power output level over the entire power output range (see ITU-T J.83 for details) and 30 dB right after or before transmission. Idle transmitter definition: A terminal is considered to be idle if it is three slots before an imminent transmission or three slots after its most recent transmission. 
I/Q amplitude imbalance	<1.0 dB
I/Q phase imbalance	<2.0º
Transmit power level at the IF modulator output (upstream)	85-113 dBμV (RMS) (75 Ω).

A.5.3 Framing

A.5.3.1 Forward Interaction path (downstream OOB)

A.5.3.1.1 Signalling Link Extended Superframe (SL-ESF) framing format

The SL-ESF frame structure is shown in Figure A.15. The bit stream is partitioned into 4632-bit Extended Superframes (ESF). Each ESF consists of 24 × 193-bit frames. Each frame consists of one Overhead (OH) bit and 24 bytes (192 bits) of payload.

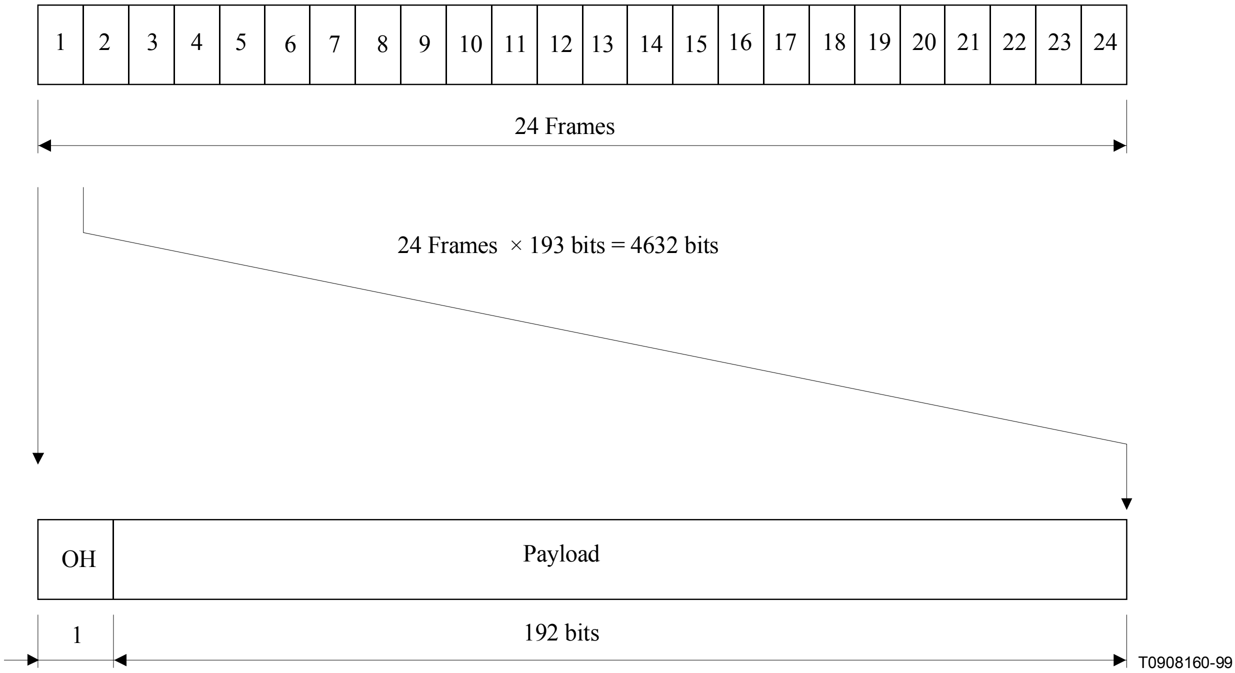


Figure A.15/J.116 – SL-ESF frame structure

A.5.3.1.2 Frame overhead

There are 24 frame Overhead (OH) bits in the ESF which are divided into ESF Frame Alignment Signal (FAS) (F1-F6), Cyclic Redundancy Check (CRC) (C1-C6), and M-bit Data Link (DL) (M1-M12) as shown in Table A.7.

Table A.7/J.116 – Frame overhead

Frame Number	Bit Number	Overhead Bit	Data (192 bits)
1	0	**M1**	
2	193	C1	
3	386	M2	
4	579	F1 = 0	
5	772	M3	
6	965	C2	
7	1158	M4	
8	1351	F2 = 0	
9	1544	**M5**	
10	1737	C3	
11	1930	M6	
12	2123	F3 = 1	
13	2316	M7	
14	2509	C4	
15	2702	M8	
16	2895	F4 = 0	

Table A.7/J.116 – Frame overhead *(concluded)*

Frame Number	Bit Number	Overhead Bit	Data (192 bits)
17	3088	**M9**	
18	3281	C5	
19	3474	M10	
20	3667	F5 = 1	
21	3860	M11	
22	4053	C6	
23	4246	M12	
24	4439	F6 = 1	
FAS Frame Alignment Signal (F1-F6) DL Mbit Data Link (M1-M12) CRC Cyclic Redundancy Check (C1-C6)			

ESF Frame Alignment Signal (FAS)

The ESF FAS is used to locate all 24 frames and overhead bit positions. The bit values of the FAS are defined as follows:

F1 = 0, F2 = 0, F3 = 1, F4 = 0, F5 = 1, F6 = 1.

ESF Cyclic Redundancy Check (CRC)

The CRC field contains the CRC-6 check bits calculated over the previous ESF. CRC Message Block (CMB) size = 4632 bits. Before calculation, all 24 frame Overhead (OH) bits are equal to "1". All information in the other bit positions is unchanged. The check bit sequence C1-C6 is the remainder after multiplication by x^6 and then division by the generator polynomial $x^6 + x + 1$ of the CMB. C1 is the MSB of the remainder. The initial remainder value is pre-set to all zeros.

ESF Mbit Data Link

The M-bits in the SL-ESF serve for slot timing assignment (see A.5.4).

A.5.3.1.3 Payload structure

The SL-ESF frame payload structure provides a known container for defining the location of the ATM cells and the corresponding Reed Solomon (RS) parity values. The SL-ESF payload structure is shown in Table A.8.

Table A.8/J.116 – ESF payload structure

	← 2 →		← 53 →	← 2 →		
1	R1a	R1b	ATM Cell	RS parity		
2	R1c	R2a			R2 b	
3	R2c	R3a				
4	R3b	R3c			R4 a	
5	R4b	R4c				
6	R5a	R5b			R5 c	
7	R6a	R6b				
8	R6c	R7a			R7 b	
9	R7c	R8a				
10	R8b	R8c			T	T

The SL-ESF payload structure consists of five rows of 57 bytes each, four rows of 58 bytes each which includes one byte trailer, and one row of 59 bytes, which includes a 2-byte trailer. The first bit of the SL-ESF payload structure follows the M1-bit of the SL-ESF frame. The SL-ESF payload fields are defined as follows.

ATM cell structure

The format for each ATM cell structure is shown in Figure A.16. This structure and field coding shall be consistent with the structure and coding given in ITU-T I.361 for ATM UNI.

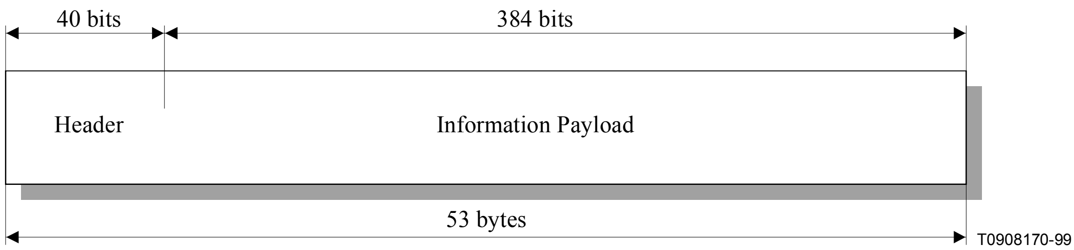


Figure A.16/J.116 – ATM cell format

Channel coding and interleaving

RS encoding with t = 1 shall be performed on each ATM cell. This means that one erroneous byte per ATM cell can be corrected. This process adds two parity bytes to the ATM cell to give a code word of (55,53).

The RS code shall have the following generator polynomials:

Code generator polynomial: $g(x) = (x + \mu^0)\,(x + \mu^1)$, where μ = 02 hex

Field generator polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

Convolutional interleaving shall be applied to the ATM cells contained in the SL-ESF. The Rxa - Rxc bytes and the two T bytes shall not be included in the interleaving process. Convolutional interleaving is applied by interleaving five lines of 55 bytes.

Following the scheme in Figure A.17, convolutional interleaving shall be applied to the error protected packets. The convolutional interleaving process shall be based on the Forney approach, which is compatible with the Ramsey type III approach, with I = 5. The interleaved frame shall be composed of overlapping error protected packets and a group of ten packets shall be delimited by the start of the SL-ESF.

The interleaver is composed of I branches, cyclically connected to the input byte-stream by the input switch. Each branch shall be a First In First Out (FIFO) shift register, with depth (M) cells (where M = N/I, N = 55 = error protected frame length, I = interleaving depth). The input and output switches shall be synchronised.

For synchronisation purposes, the first byte of each error protected packet shall be always routed into the branch "0" of the interleaver (corresponding to a null delay). The third byte of the SL-ESF payload (the byte immediately following R1b) shall be aligned to the first byte of an error protected packet.

The de-interleaver is similar, in principle, to the interleaver, but the branch indexes are reversed (i.e. branch 0 corresponds to the largest delay). The de-interleaver synchronisation is achieved by routing the third data byte of the SL-ESF into the "0" branch.

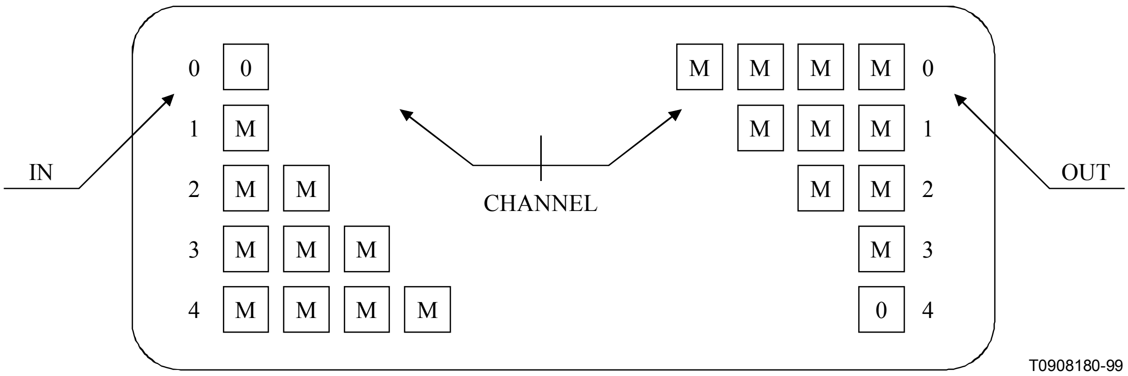


Figure A.17/J.116 – Interleaver and de-interleaver structures

Reception indicator fields and slot boundary fields

Rxa-Rxc is a 24-bit field containing slot configuration information for the upstream channel "x" and is defined as:

Rxa = (b0 ... b7)

Rxb = (b8 ... b15)

Rxc = (b16 ... b23)

= slot configuration information for the upstream channel "x" where "x" is indicated to the NIU in the "Flag set" given in MAC messages (Default Configuration Message, Connect Message, Transmission Control message) corresponding to a particular upstream frequency. One channel requires two consecutive fields. "x" thus denotes first field used for a particular upstream frequency.

b0 = ranging control slot indicator for next superframe

b1-b6 = slot boundary definition field for next superframe

b7 = slot 1 reception indicator for second previous superframe

b8 = slot 2 reception indicator for second previous superframe

b9 = slot 3 reception indicator for second previous superframe

b10	= slot 4 reception indicator for second previous superframe
b11	= slot 5 reception indicator for second previous superframe
b12	= slot 6 reception indicator for second previous superframe
b13	= slot 7 reception indicator for second previous superframe
b14	= slot 8 reception indicator for second previous superframe
b15	= slot 9 reception indicator for second previous superframe
b16-17	= reservation control for next superframe
b18-b23	= CRC-6 parity

The nine slots of this field and the 9 slots of the following field are valid.

Ranging control slot indicator (b0): When this bit is active (b0 = 1), the first three slots of upstream channel "x" which correspond to the occurrence of the next superframe of the related downstream channel are designated as ranging control slots. A ranging control message may be transmitted in the second ranging control slot, and the first and third ranging control slots may not be used for transmission (guardband for ranging operations).

Slot boundary definition field (b1-b6): Slot types are assigned to upstream slots using bits b0-b6. The slots are grouped into regions within the SL-ESF such that slots of a similar type are contained within the same region. The order of the regions is Ranging slot, Contention based slots, Reserved slots and Fixed rate based slots. If a ranging slot is available within a SL-ESF it will consist of the first three slot times in the SL-ESF. A ranging slot is indicated by b0 = 1. The boundaries between the remaining regions of the SL-ESF are defined by b1-b6. The boundaries are defined as shown in Table A.9.

Table A.9/J.116 – Slot boundary definition field (b1-b6)

Boundary 0	
Boundary 1	slot 1
Boundary 2	slot 2
Boundary 3	slot 3
Boundary 4	slot 4
Boundary 5	slot 5
Boundary 6	slot 6
Boundary 7	slot 7
Boundary 8	slot 8
Boundary 9	slot 9

The boundary positions are defined by b1-b6 as shown in Table A.10.

Table A.10/J.116 – Boundary positions (b1-b6)

(Note 1) (Note 2)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0 (Note 3)	0	1	2	3	4	5	6	7	8	9
1 (Note 3)		10	11	12	13	14	15	16	17	18
2 (Note 3)			19	20	21	22	23	24	25	26
3				27	28	29	30	31	32	33
4					34	35	36	37	38	39
5						40	41	42	43	44
6							45	46	47	48
7								49	50	51
8									52	53
9										54

NOTE 1 – Row = Contention based/Reserved region boundary.

NOTE 2 – Column = Reserved packet /Fixed rate based region boundary.

NOTE 3 – When the ranging control slot indicator (b0) is set to "1", the values in rows 0-2 are illegal values, and values in row 3 means that there are no aloha slots, because slots 1-3 are defined as ranging control slots.

Example: b0 = 0, b1-b6 = 22: contention (1-2), reserved (3-5), fixed rate (6-9)

The remaining values of the slot boundary definition field are provided in Table A.11.

Table A.11/J.116 – Slot boundary definition field

b1-b6 value	**Ranging control slots**	**Contention slots**	**Reservation slots**	**Fixed rate slots**
55	1-6	7-9	–	–
56	1-6	7-8	–	9
57	1-6	7	8-9	–
58	1-6	7	8	9
59	1-6	7	–	8-9
60	1-6	–	7-8	9
61	1-6	–	7	8-9
62	1-6	–	–	7-9
63	1-9	–	–	–

For b1-b6 = 55-63, b0 shall be set to 1.

For b1-b6 between 55 and 62, two ranging slots are provided (2 and 5).

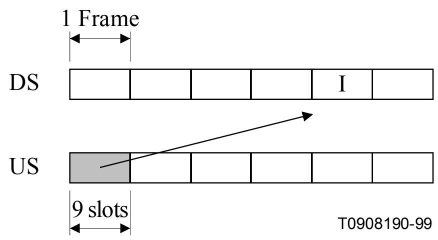
For b1-b6 = 63, three ranging slots are provided (2, 5 and 8).

The values in Tables A.11 to A.13 are derived from b1-b6 in the following manner:

$$b1 + (b2 \times 2) + (b3 \times 4) + (b4 \times 8) + (b5 \times 16) + (b6 \times 32)$$

Slot reception indicators (b7-b15): When a slot reception indicator is active ("1"), this indicates that a cell was received without collision. The relationship between a given US slot and its indicator is shown in Table A.12. When the indicator is inactive ("0"), this indicates that either a collision was detected or no cell was received in the corresponding upstream slot.

Table A.12/J.116 – Relationship of US slot to DS indicator

	1.544 M downstream	**3.088 M downstream**
256 k	Non-applicable	Non-applicable
1.544 M	Non-applicable	Non-applicable
3.088 M	Non-applicable	
	I indicates the DS slot in which Indicators are sent. These indicators are for the US slots in the shaded area.	

Reservation control (b16-b17): When the reservation control field has the value of 0, no reservation attempts are allowed to be transmitted on the corresponding QPSK upstream channel during the slot positions associated with the next 3 ms period. When the reservation control field has the value of 1, reservation attempts can be made. The values 2 and 3 are reserved.

CRC-6 parity (b18-b23): This field contains a CRC-6 parity value calculated over the previous 18 bits. The CRC-6 parity value is described in the SL-ESF frame format.

In the case where there is more than one OOB DS QPSK channel related to an upstream QPSK channel, the SL-ESF overhead bits and the payload R-bytes shall be identical in those OOB DS channels, with the exception of the overhead CRC (C1-C6) bits, which are specific to each of those OOB DS channels. Such related DS channels shall be synchronised.

The MAC messages that are required to perform the MAC functions for the upstream channel shall be transmitted on each of its related OOB DS channels.

Trailer bytes

These bytes are not used. They are equal to 0.

A.5.3.2 Forward interaction path (downstream IB)

The structure that is utilised when the downstream QPSK channel is carrying MPEG2-TS packets is shown in Figure A.18.

4	**3**	**2**	**3**	**26**	**26**	**40**	**40**	**40**	**4**
MPEG Header	Upstrm Marker	Slot Number	MAC Flg Control	MAC Flags	Ext. Flags	MAC msg.	MAC msg.	MAC msg.	rsrvc

Figure A.18/J.116 – Frame structure (MPEG2-TS format)

where:

MPEG header is the 4-byte MPEG2-TS header as defined in ISO/IEC 13818-1 with a specific PID designated for MAC messages.

upstream marker is a 24-bit field which provides upstream QPSK synchronisation information. The definition of the field is as follows:

> **bit 0: upstream marker enable** (MSB)
>
> When this field has the value "1", the slot marker pointer is valid. When this field has the value "0", the slot marker pointer is not valid.
>
> **bit 1-7: reserved**
>
> **bit 8-23: upstream slot marker pointer**
>
> The slot marker pointer is a 16-bit integer which indicates the number of "symbol" clocks between the first symbol of the next sync byte and the next 3 ms marker.

slot number is a 16-bit field which is defined as follows:

> **bit 0: slot position register enable** (MSB)
>
> When this field has the value "1", the slot position register is valid. When this field has the value "0", the slot position register is not valid.
>
> **bit 1-3: reserved**
>
> **bit 4** is set to the value "1". This bit is equivalent to M12 in the case of OOB downstream.
>
> **bit 5: odd parity**
>
> This bit provides odd parity for upstream slot position register. This bit is equivalent to M11 in the case of OOB downstream.
>
> **bits 6-15: upstream slot position register**
>
> The upstream slot position register is a 10-bit counter which counts from 0 to n with bit 6 the MSB. These bits are equivalent to M10-M1 in the case of OOB downstream (see A.5.4 for more information on the functionality of the upstream slot position register).

MAC Flag Control is a 24-bit field (b0, b1, b2...b23) which provides control information which is used in conjunction with the MAC flags and extension flags. The definition of the MAC flag control field is as follows:

b0-b2	channel 1 flag field control
b3-b5	channel 2 flag field control
b6-b8	channel 3 flag field control
b9-b11	channel 4 flag field control
b12-b14	channel 5 flag field control
b15-b17	channel 6 flag field control
b18-b20	channel 7 flag field control
b21-b23	channel 8 flag field control

Each of the above channel "x" flag field control fields are defined as follows:

> channel x flag control (a, b, c)
>
> bit a: 0 – channel x flag field disabled
>
> 1 – channel x flag field enabled

bit b, c: 00 – all flags valid for second previous 3 ms period
(out-of-band signalling equivalent)
01 – flags valid for 1st ms of previous 3 ms period
10 – flags valid for 2nd ms of previous 3 ms period
11 – flags valid for 3rd ms of previous 3 ms period

MAC Flags

MAC Flags is a 26-byte field containing eight slot configuration fields (24 bits each) which contain slot configuration information for the related upstream channels followed by two reserved bytes. The definition of each slot configuration field is defined as follows:

b0 = ranging control slot indicator for next 3 ms period (MSB)
b1-b6 = slot boundary definition field for next 3 ms period
b7 = slot 1 reception indicator for [second] previous 3 ms period
b8 = slot 2 reception indicator for [second] previous 3 ms period
b9 = slot 3 reception indicator for [second] previous 3 ms period
b10 = slot 4 reception indicator for [second] previous 3 ms period
b11 = slot 5 reception indicator for [second] previous 3 ms period
b12 = slot 6 reception indicator for [second] previous 3 ms period
b13 = slot 7 reception indicator for [second] previous 3 ms period
b14 = slot 8 reception indicator for [second] previous 3 ms period
b15 = slot 9 reception indicator for [second] previous 3 ms period
b16-17 = reservation control for next 3 ms period
b18-b23 = CRC-6 parity

The slot configuration fields are used in conjunction with the MAC flag control field defined above. When the MAC flag control field designates that a 1 ms flag update is enabled:

1) the reception indicators refer to the previous 3 ms period (the bracketed term [second] is omitted from the definition);
2) only the reception indicators which relate to slots which occur during the designated 1 ms period are valid; and
3) the ranging control slot indicator, slot boundary definition field, and reservation control field are valid and consistent during each 3 ms period.

MAC Message

The MAC Message field contains a 40-byte message, the general format defined in A.5.5.

reserve field c is a 4-byte field reserved for future use.

A.5.3.3 Return interaction path (upstream)

A.5.3.3.1 Slot format

The format of the upstream slot is shown in Figure A.19. A Unique Word (UW) (4 bytes) provides a burst mode acquisition method. The payload area (53 bytes) contains a single message cell. The RS parity field (6 bytes) provides t = 3 Reed Solomon protection RS(59,53) over the payload area. The guardband (1 byte) provides spacing between adjacent packets.

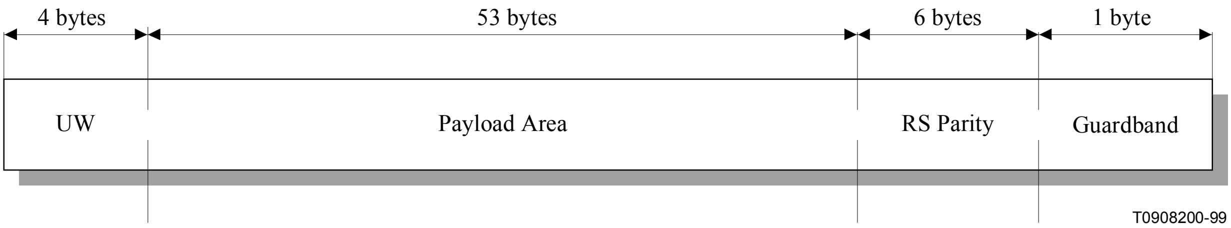


Figure A.19/J.116 – Slot format

The structure and field coding of the message cell shall be consistent with the structure and coding given in ITU-T I.361 for ATM UNI.

Unique Word (UW)

The UW is four bytes long: 0x 00 FC FC F3.

ATM cell structure

The format for each ATM cell structure is given in Figure A.20. This structure and field coding shall be consistent with the structure and coding given in ITU-T I.361 for ATM UNI.

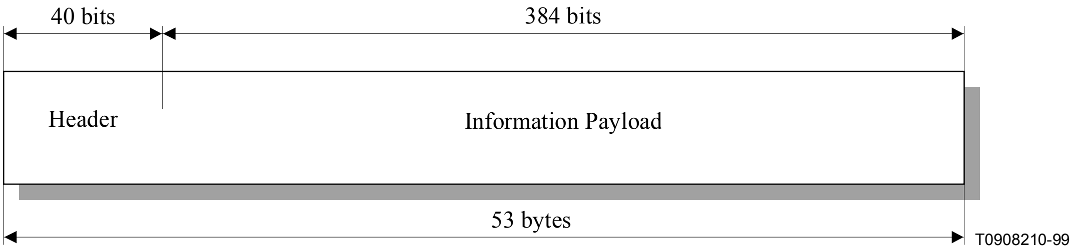


Figure A.20/J.116 – ATM cell format

Channel coding

RS encoding shall be performed on each ATM cell with T = 3. This means that 3 erroneous byte per ATM cell can be corrected. This process adds 6 parity bytes to the ATM cell to give a code word of (59,53).

The RS code shall have the following generator polynomials:

Code generator polynomial:

$$g(x) = (x + \mu^0)\,(x + \mu^1)\,(x + \mu^2)\ ...\ (x + \mu^5)$$

where μ = 02 hex

Field generator polynomial:

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1$$

Guardband

The guardband is 1-byte long (4 QPSK symbols). It provides some extra protection against synchronisation errors.

A.5.4 Slot timing assignment

A.5.4.1 Downstream slot position reference (downstream OOB)

Upstream synchronisation is derived from the downstream extended superframe (OOB) by noting the slot positions as shown in Table A.13.

Table A.13/J.116 – Downstream slot position reference

Frame Number	Bit Number	Overhead Bit	Slot position reference
1	0	**M1**	• Slot Position (Note)
2	193	C1	
3	386	M2	
4	579	F1 = 0	
5	772	M3	
6	965	C2	
7	1158	M4	
8	1351	F2 = 0	
9	1544	**M5**	• Slot Position
10	1737	C3	
11	1930	M6	
12	2123	F3 = 1	
13	2316	M7	
14	2509	C4	
15	2702	M8	
16	2895	F4 = 0	
17	3088	**M9**	• Slot Position
18	3281	C5	
19	3474	M10	
20	3667	F5 = 1	
21	3860	M11	
22	4053	C6	
23	4246	M12	
24	4439	F6 = 1	
NOTE – For the 3.088 Mbit/s rate downstream, the 3 ms time marker only appears once every two superframes. The M12 bit (see A.5.4) is used to differentiate between the two superframes.			

A.5.4.2 Downstream slot position reference (downstream IB)

Upstream synchronisation is derived from the downstream extended superframe (IB) by noting the 3 ms time marker downstream as shown in Figure A.21. From the bits of the upstream marker field contained in the MPEG2-TS packet, the 3 ms time marker is obtained by counting a number of symbol clocks equal to (b23-b8). This marker is equivalent to the first slot position of the superframe for the OOB case.

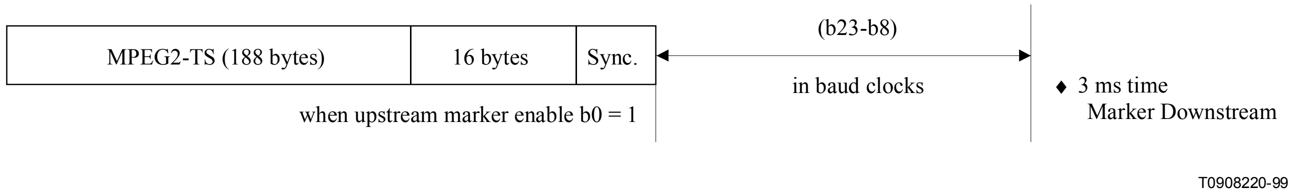


Figure A.21/J.116 – Position of the 3 ms time marker for IB signalling

In order to describe how the upstream marker is derived from the location of the 3 ms marker, consider the following system diagram. See Figure A.22.

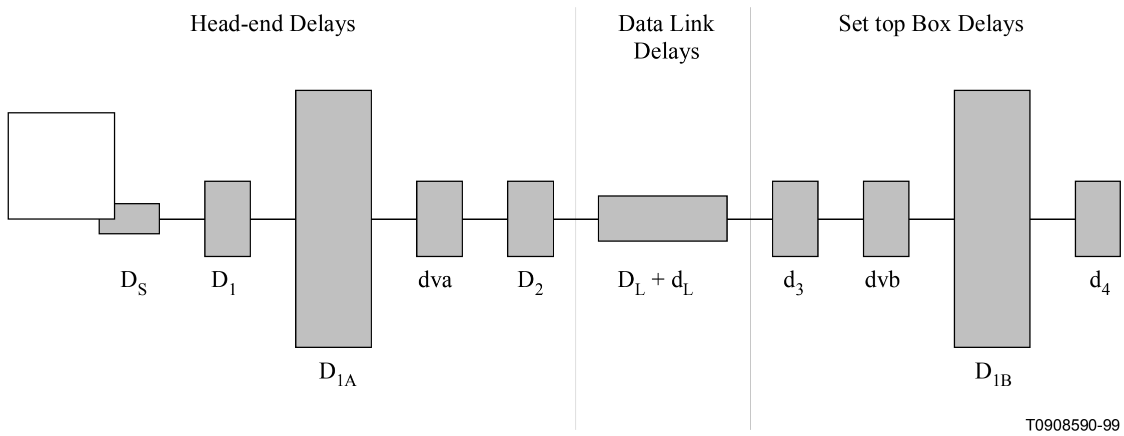


Figure A.22/J.116 – System model for timing analysis

The delay between the location of the end of the upstream marker and the beginning of the next sync byte, designated as D_S, is a constant value for each bit rate equal to the equivalent time of 194 bytes, or ($194 \times 8/2$) symbol clocks.

There will be some processing delay in the head-end hardware between the location where the upstream marker is inserted in the MAC packet and the arrival of the data into the interleaver. This should be a constant delay, D_1, which is the same for every incoming byte, including the sync byte following the upstream marker.

The delay due to the interleaving process in the head-end is D_{IA} and will be zero for each sync byte.

There is an additional delay, dva, due to the convolutional coding process if any; this delay will be code rate dependent, according to the DVB-MS specification (it is also design dependent).

There will be some processing delay in the head-end hardware between the output of the inner coder and the output of the QPSK modulator. This should be a constant delay, D_2, for every byte in the outgoing stream.

The data link is composed of two delay values, D_L, the constant link delay that every STU experiences, and d_L, the variable link delay for each STU which is due to the fact that each STU is located at a different distance from the head-end. This variable link delay is compensated for by the ranging operation.

There will be some processing delay in the STU hardware between the input of the QPSK demodulator and the input of the convolutional decoder. This delay is design dependent, d_3, and may be a constant delay or a variable delay for each byte in the data stream.

There is an additional delay, dvb, which is due to the convolutional decoder; this delay is code rate dependent, according to the DVB-MS specification. It is also design dependent.

The delay due to the de-interleaving process in the STU is D_{IB}, and will be equal to the entire interleave delay for each sync byte.

The total interleave delay, $D_I = D_{IA} + D_{IB}$

will be constant for each byte. The value will be given by:

$$D_I = 204 \times 8 \times \text{interleave\_depth/bit rate}$$

There will be some processing delay in the STU hardware between the output of the de-interleaver and the circuitry that utilises the upstream marker and following sync byte for generating the local 3 ms marker. This delay, which includes RS FEC, is design dependent, d_4, and may be a constant delay or a variable delay for each byte in the data stream.

The accumulated delay in the data link is composed of a number of constant terms and variable terms. The constant terms will be identical for every STU that is utilising a particular QPSK channel for in-band timing and thus becomes a fixed offset between when the counter which is loading the upstream marker value and the actual location of the 3 ms marker at each STU. Each STU is responsible for compensating for the design dependent delays, before utilising the upstream marker value for generating the 3 ms marker. The variable link delay, d_L, will be compensated for via the ranging algorithm, in the same way as performed when out-of-band signalling is employed.

A.5.4.3 Upstream slot positions

Transmission on each QPSK upstream channel is based on dividing access by multiple NIU units by utilising a negotiated bandwidth allocation slot access method. A slotting methodology allows the transmit slot locations to be synchronous to a common slot position reference, which is provided via the related downstream MAC control channel. Synchronising the slot locations increases message throughput of the upstream channels since the ATM cells do not overlap during transmission.

The slot position reference for upstream slot locations is received via the related downstream MAC control channel by each NIU. Since each NIU receives the downstream slot position reference at a slightly different time, due to propagation delay in the transmission network, slot position ranging is required to align the actual slot locations for each related upstream channel. The upstream slot rates are 6000 upstream slots/s.

The number of slots available in any one second is given by:

number of slots/s = upstream data rate/512 + (extra guardband)

where extra guardband may be designated between groups of slots for alignment purposes. The M-bits in the SL-ESF serve two purposes:

– to mark the slot positions for the upstream contention based and contentionless based signalling links (see A.5.4.4);

– to provide slot count information for upstream message bandwidth allocation management in the NIU.

M-bits M1, M5, and M9 mark the start of an upstream slot position for upstream message transmission.

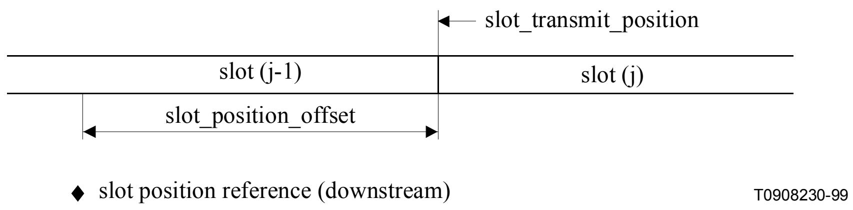
<table>
<tr><th colspan="18">3 ms period</th><th></th><th></th></tr>
<tr><td>k</td><td>k + 1</td><td>k + 2</td><td>k + 3</td><td>k + 4</td><td>k + 5</td><td>k + 6</td><td>k + 7</td><td>k + 8</td><td>k + 9</td><td>k + 10</td><td>k + 11</td><td>k + 12</td><td>k + 13</td><td>k + 14</td><td>k + 15</td><td>k + 16</td><td>k + 17</td><td>k + 18</td><td>k + 19</td></tr>
</table>

As the downstream and upstream bit rates are 3.088 Mbit/s, there are six slot position references downstream during the transmission of 18 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

The relationship between the received slot position reference and the actual slot transmit position is given by:

slot_transmit_position = slot_position_reference + slot_position_offset

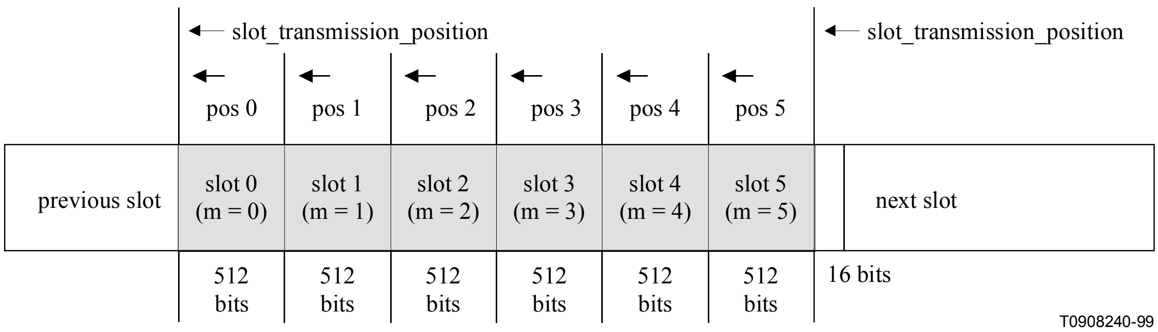
where slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message.



The actual slot transmission locations are given by:

slot_transmission_location (m) = slot_transmission_position + (m $\times$ 512)

where m = 0,1,2,3,4,5; is the position of the slot with respect to the slot_transmission_position



A.5.4.4 Slot position counter

Think of M-bits M10-M1 as a register, called the upstream slot position register, which is used to generate an upstream slot position counter, which counts from 0 to n, where n is an integer which indicates slot position cycle size (the value of n is sent in the MAC default configuration message as Service_Channel_Last_Slot). The upstream slot position register indicates the upstream slot positions that will correspond to the next SL-ESF frame. Upstream slot positions are counted from 0 to n. There are 6 upstream slots per millisecond. The corresponding upstream slot rates are, therefore, 6000 upstream slots/s when the upstream data rate is 3.088 Mbit/s. The algorithm to determine the upstream slot position counter value is given below:

{n = 1;}

upstream_slot_position_register = value of M-bits latched at bit_position M11 (M10-M1)

{m = 6;}

if (bit_position = M1 and previous M12 = 1)

{ upstream_slot_position_counter = upstream_slot_register * 3 * m; }

if (bit_position == M5)

```
        if (previous M12 0) )
              { upstream_slot_position_counter =
                upstream_slot_position_counter+m; }
if (bit_position == M9)
        if (previous M12 = 1) )
        { upstream_slot_position_counter = upstream_slot_position_counter + m; }
if (bit_position = M11)
        { temp_upstream_slot_position_register = (M10, M9, M8, ..., M1); }
if ( (bit_position = M12 and M12 = 1) )
        {upstream_slot_position = temp_upstream_slot_position_register;}
```

where, the M-bits will be defined as follows:

M1-M10 =	10-bit ESF counter which counts from 0 to n with M10 the MSB;
M11 =	odd parity for the ESF counter, i.e. M11 = 1 if the ESF_value (M1-M10) has an even number of bits set to 1;
M12 =	1: ESF counter valid; 0: ESF counter not valid.

The values assigned to M12 are as follows:

The information is always transmitted in pairs of superframe, where superframe A is the first superframe in the pair, and superframe B is the second superframe in the pair. The M12 bit of superframe A is set to the value "0" and the M12 bit of superframe B is set to the value "1".

When the downstream channel is IB, M12 = 1.

A.5.5 MAC functionality

A.5.5.1 MAC reference model

This clause is limited to the definition and specification of the MAC layer protocol. The detailed operations within the MAC layer are hidden from the above layers.

This clause focuses on the required message flows between the INA and the NIU for MAC. These areas are divided into three categories:

1) initialisation, provisioning and sign-on management;
2) connection management; and
3) link management.

See Figure A.23.

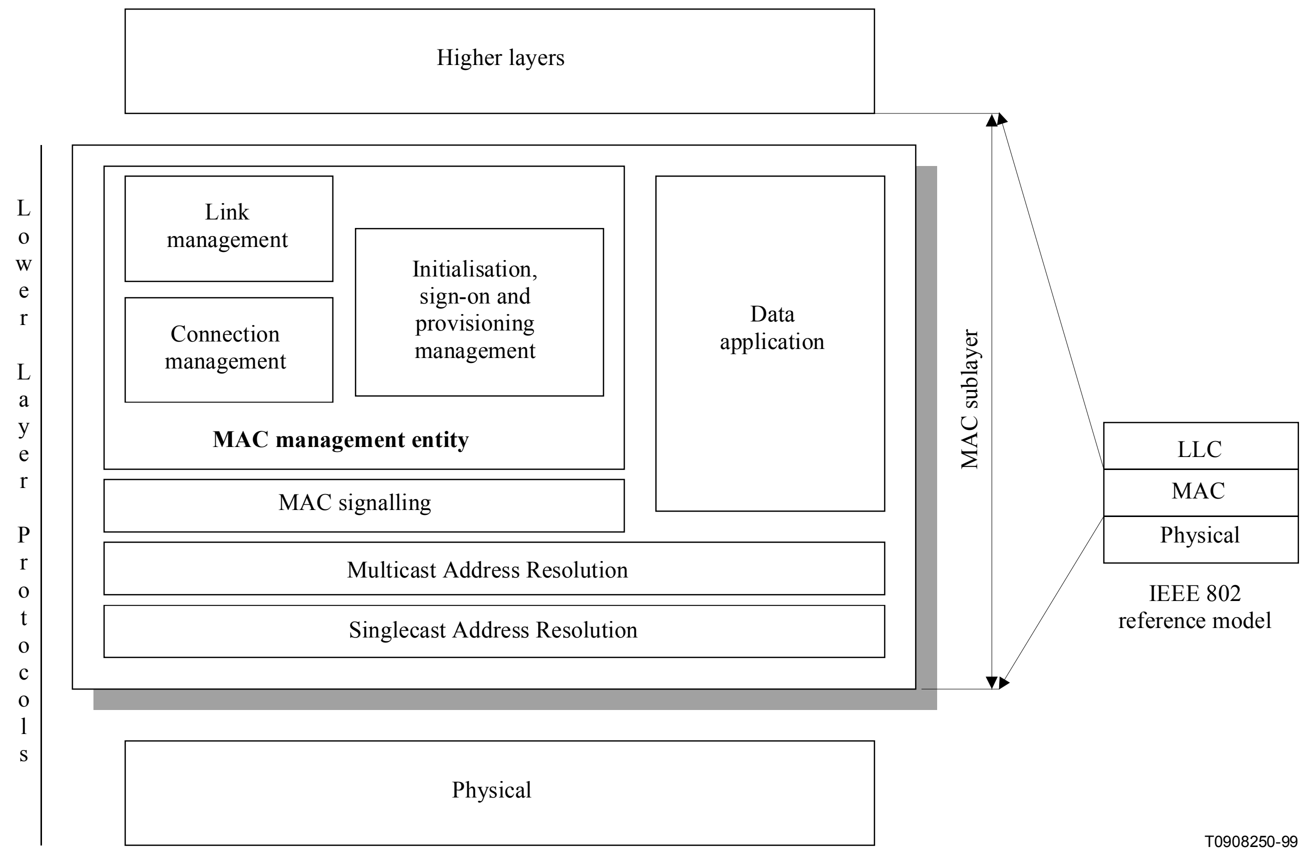


Figure A.23/J.116 – MAC reference model

A.5.5.2 MAC concept

A.5.5.2.1 Relationship between higher layers and MAC protocol

The goal of the MAC protocol is to provide tools for higher layer protocols in order to transmit and receive data transparently and independently of the physical layer. Higher layer services are provided by the INA to the STU. The INA is thus responsible for indicating the transmission mode and rate to the MAC layer for each type of service.

Specifically, for each connection provided by higher layers on the INA side (VPI/VCI), a connection ID is associated at the MAC layer. The maximum number of simultaneous connections that a NIU should support is defined as follows:

Grade A: Only one connection at a time can be handled by a NIU.

Grade B: As many connections as needed, defined dynamically by the INA, following higher layers' requests.

However, bandwidth (time slots) does not need to be assigned immediately by the INA for a given connection. This means that a connection ID may exist at the NIU side without associated slot numbers.

The INA is responsible of providing transmission bandwidth to the NIU's when needed by higher layers. However, since the NIU shall transmit all data from the STU, the NIU is also responsible for requesting for more bandwidth if not already provided by the INA.

A default connection is initiated by the INA when STBs are first turned on. This connection can be used to send data from higher layers leading to further interactive connections. This connection can be associated to a zero transmission rate (no initial bandwidth allocation).

A.5.5.2.2 Relationship between physical layer and MAC protocol

Up to 8 QPSK Upstream channels can be related to each downstream channel which is designated as a MAC control channel. An example of frequency allocation is shown in the Figure A.24. This relationship consists of the following items:

1) Each of these related upstream channels share a common slot position. This reference is based on 1 ms time markers that are derived via information transmitted via the downstream MAC control channel.
2) Each of these related upstream channels derive slot numbers from information provided in the downstream MAC control channel.
3) The messaging needed to perform MAC functions for each of these related upstream channels is transmitted via the downstream MAC control channel.

The MAC protocol supports multiple downstream channels. In instances where multiple channels are used, the INA shall specify a single OOB frequency called the Provisioning Channel, where NIUs perform Initialisation and Provisioning Functions. In networks where IB NIUs exist, provisioning should be included in at least one IB channel. An aperiodic message is sent on each downstream control channel which points to the downstream Provisioning Channel. In instances where only a single frequency is in use, the INA shall utilise that frequency for Initialisation and Provisioning functions.

The MAC protocol supports multiple upstream channels. One of the upstream channels shall be designated the Service Channel. The Service Channel shall be used by NIUs entering the network via the Initialisation and Provisioning procedure. The remaining upstream channels shall be used for upstream data transmission. In cases where only one upstream channel is utilised, the functions of the Service Channel shall reside in conjunction with regular upstream data transmission.

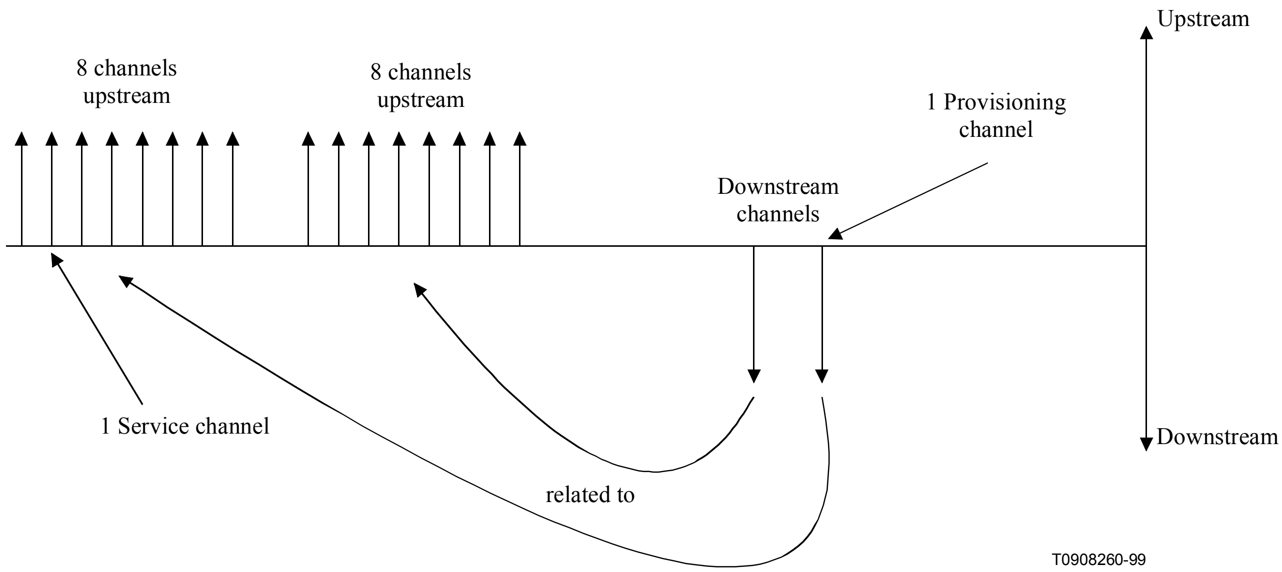


Figure A.24/J.116 – Example of frequency allocation

A.5.5.2.3 Relationship between physical layer slot position counter and MAC slot assignment

M10-M1 is a 10-bit superframe counter at the INA side, whereas the upstream slot position counter is an upstream slot counter at the NIU's side. The NIU slot position counter (M10-M1 $\times 3 \times$ m, where m = 6) may be implemented as a 16-bit counter which is compared to the 16-bit slot numbers assigned by the INA in MAC messages (list assignment). When the counter value equals any assigned value, the NIU is allowed to send a packet upstream.

In the algorithm given in A.5.4.3, the counter value is refreshed every time M11 is received.

A.5.5.2.4 Access modes (contention/ranging/fixed rate/reservation)

Different access modes are provided to the NIU's within access regions specified by information contained in the slot boundary fields of the downstream superframes. The limits between access regions allow users to know when to send data on contention without risks of collision with contentionless type data. The following rules define how to select access modes:

Data connections

When the INA assigns a connection ID to the NIU, it either specifies a slot list to be used (Fixed rate access) or the NIU shall use contention or reserved access by following this algorithm:

When the NIU shall send more cells than what was assigned by the INA, it can use contention access only if the number of cells to transmit is less than Maximum_contention_access_message_length (specified in the MAC Connect Message from the INA). In that case, it shall wait for the slot reception indicator before it is allowed to send other cells with the same VPI/VCI value. The NIU can send one request for reservation access if the number of cells is less than Maximum_reservation_access_message_length (specified in the MAC Connect Message from the INA). If more cells shall be transmitted, the NIU shall send multiple requests for reservation access.

MAC messages

MAC messages can be sent on contention access or reservation access. MAC messages sent upstream shall be less than 40 bytes long. If the MAC information exceeds 40 bytes, it shall be segmented into multiple 40 bytes independent MAC messages. Ranging access can only be used for specific MAC messages.

a) *Contention access*

Contention access indicates that data (MAC or bursty data traffic) is sent in the slots assigned to the contention access region in the upstream channel. It can be used either to send MAC messages or data. The VPI, VCI of the ATM cells are then used to determine the type and direction of the data in higher layers. Contention based access provides instant channel allocation for the NIU.

The Contention based technique is used for multiple subscribers that will have equal access to the signalling channel. It is probable that simultaneous transmissions will occur. For each ATM cell transmitted by the NIU, a positive acknowledgement is sent back by the INA, utilising the reception indicator field, for each successfully received ATM cell. In contention based access mode, a positive acknowledgement indicates that a collision did not occur. A collision occurs if two or more NIUs attempt ATM cell transmission during the same slot. A collision will be assumed if a NIU does not receive a positive acknowledgement. If a collision occurs, then the NIU will retransmit using a procedure to be defined by the implementer.

b) *Ranging access*

Ranging access indicates that the data is sent in a slot preceded and followed by slots not used by other users. These slots allow users to adjust their clock depending on their distance to the INA such that their slots fall within the correct allocated time. They are either contention based when the ranging control slot indicator b0 received during the previous superframe was 1 (or when b1-b6 = 55 to 63), or reserved if the INA indicates to the NIU that a specific slot is reserved for ranging.

c) *Fixed rate access*

Fixed rate access indicates that data is sent in slots assigned to the fixed rate based access region in the upstream channel. These slots are uniquely assigned to a connection by the INA. No fixed rate access can be initiated by the NIU.

d) *Reservation access*

Reservation access implies that data is sent in the slots assigned to the reservation region in the upstream channel. These slots are uniquely assigned on a frame by frame basis to a connection by the INA. This assignment is made at the request of the NIU for a given connection.

A.5.5.2.5 MAC error handling procedures

Error handling procedures are under definition (Time out windows, retransmission, power outage, etc.).

A.5.5.2.6 MAC messages

The MAC message types are divided into the logical MAC states of Initialisation, Sign-On, Connection Management and Link Management. Messages in italic represent upstream transmission from NIU to INA. MAC messages are sent using Broadcast or Singlecast Addressing. Singlecast address shall utilise the 48-bit MAC address. See Table A.14.

Table A.14/J.116 – MAC messages

Message Type Value		Addressing Type
	MAC Initialisation, Provisioning and Sign-On Message	
0x01	Provisioning Channel Message	Broadcast
0x02	Default Configuration Message	Broadcast
0x03	Sign-On Request Message	Broadcast
0x04	*Sign-On Response Message*	Singlecast
0x05	Ranging and Power Calibration Message	Singlecast
0x06	*Ranging and Power Calibration Response Message*	Singlecast
0x07	Initialisation Complete Message	Singlecast
0x08-0x1F	[Reserved]	
0x20-0x3F	**MAC Connection Establishment and Termination Msgs**	
0x20	Connect Message	Singlecast
0x21	*Connect Response Message*	Singlecast
0x22	*Reservation Request Message*	Singlecast
0x23	Reservation Response Message	Broadcast
0x24	Connect Confirm Message	Singlecast
0x25	Release Message	Singlecast
0x26	*Release Response Message*	Singlecast
0x27	*Idle Message*	Singlecast
0x28	Reservation Grant Message	Broadcast
0x29	Reservation ID Assignment	Singlecast
0x2A	*Reservation Status Request*	Singlecast

Table A.14/J.116 – MAC messages *(concluded)*

Message Type Value		Addressing Type
0x2B	*Reservation ID Response Message*	Singlecast
0x2C-0x3F	[Reserved]	
	MAC Link Management Messages	
0x27	*Idle Message*	Singlecast
0x40	Transmission Control Message	Singlecast or Broadcast
0x41	Reprovision Message	Singlecast
0x42	*Link Management Response Message*	Singlecast
0x43	Status Request Message	Singlecast
0x44	*Status Response Message*	Singlecast
0x45-0x5F	[Reserved]	

To support the delivery of MAC related information to and from the NIU, a dedicated Virtual Channel shall be utilised. The VPI, VCI for this channel shall be 0x000, 0x0021.

Upstream MAC messages

AAL5 (as specified in ITU-T I.363) adaptation shall be used to encapsulate each MAC PDU in an ATM cell. Upstream MAC information should be single 40 bytes cell messages.

Downstream OOB MAC messages

AAL5 (as specified in ITU-T I.363) adaptation shall be used to encapsulate each MAC PDU in an ATM cell. Downstream OOB MAC information may be longer than 40 bytes.

Downstream IB MAC messages

Downstream IB MAC information is limited to 120-byte long messages (a procedure to be able to send longer messages is under definition). No AAL5 layer is defined for MPEG2-TS cells. MAC messages shall therefore be sent as explained in Figure A.25.

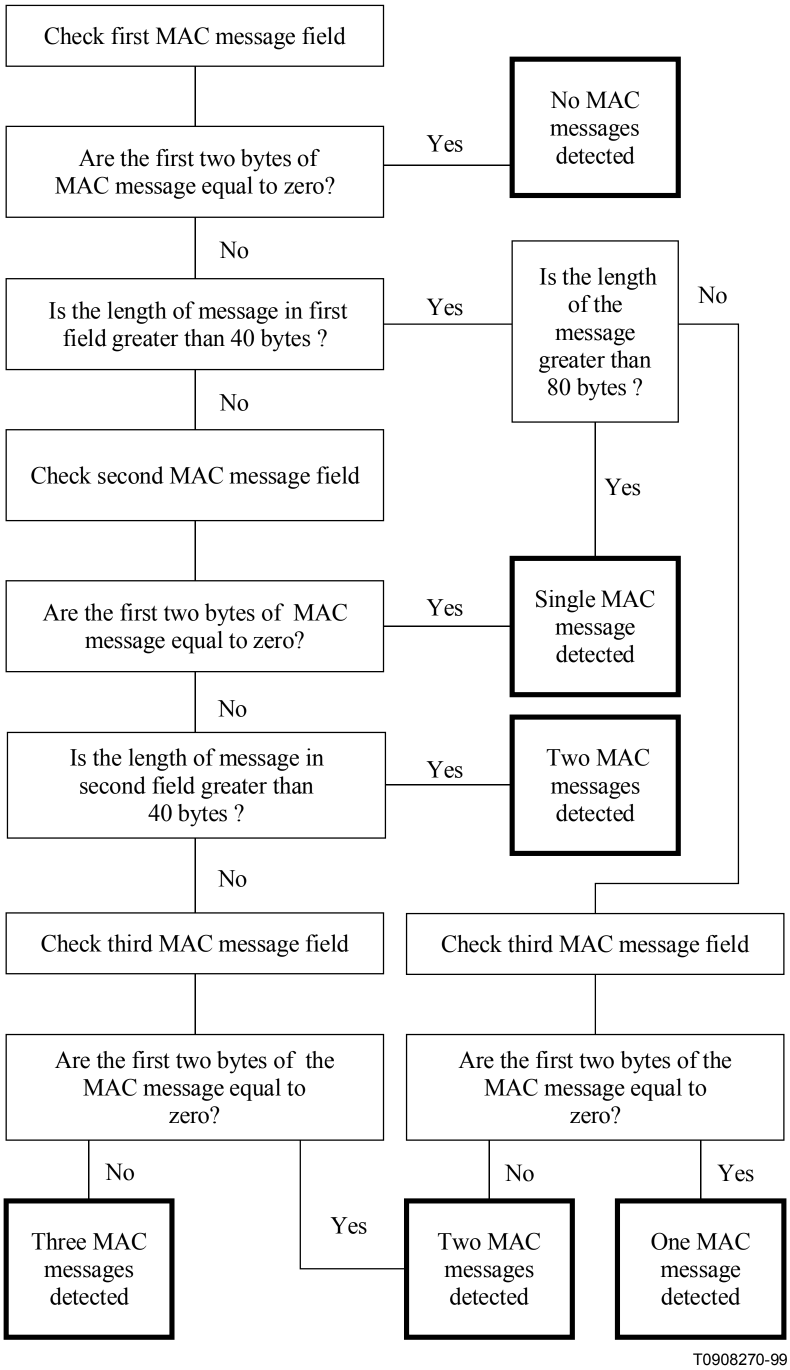


Figure A.25/J.116 – Algorithm when MAC message are sent IB downstream

Since MAC related information is terminated at the NIU and INA a privately defined message structure will be utilised. The format of this message structure is illustrated in Table A.15. All messages are sent most significant bit first. Message 0x23 is not used in the present release of the MAC protocol. When no MAC_Address is specified in the message, it means that the message is sent broadcast. (Syntax_indicator = 000.)

Table A.15/J.116 – MAC message structure

MAC_message(){	Bits	Bytes	Bit Number/Description
Message_Configuration	**8**	**1**	
Protocol_Version	5		
Syntax_Indicator	3		
Message_Type	**8**	**1**	
if (syntax_indicator= 001) {			
MAC_Address	**(48)**	**(6)**	
}			
{			
MAC_Information_Elements ()		**N**	
}			

Protocol Version

Protocol_Version is a 5-bit field used to identify the current MAC version. The value for this parameter is given in Table A.16.

Table A.16/J.116 – Protocol_version coding

Value	Definition
0-31	Reserved

Syntax Indicator

Syntax_Indicator is a 3-bit enumerated type that indicates the addressing type contained in the MAC message. See Table A.17.

Table A.17/J.116

Enum Syntax_Indicator {No_MAC_Address, MAC_Address_Included, reserved2..7};

MAC Address

MAC_Address is a 48-bit value representing the unique MAC address of the NIU. This MAC address may be hard coded in the NIU or be provided by external source.

A.5.5.3 MAC initialisation and provisioning

This clause defines the procedure for initialisation and provisioning that the MAC shall perform during power on or reset.

1) Upon a NIU becoming active (i.e. powered up), it shall first find the current provisioning frequency. The NIU shall receive the **<MAC> Provisioning Channel Message**. This message shall be sent aperiodically on all downstream OOB channels when there are multiple channels. In the case of only a single channel, the message shall indicate the current channel to be utilised for Provisioning. Upon receiving this message, the NIU shall tune to the Provisioning Channel.

2) After a valid lock indication on a Provisioning Channel, the NIU shall await the **<MAC> DEFAULT CONFIGURATION MESSAGE**. When received, the NIU shall configure its parameters as defined in the default configuration message. The Default Configuration Parameters shall include default timer values, default power levels, default retry counts as well as other information related to the operation of the MAC protocol.

Figure A.26 shows the signalling sequence.

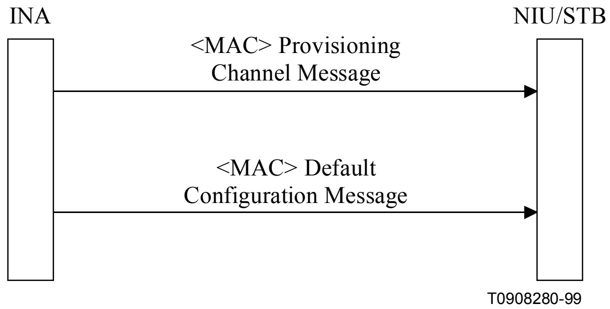


Figure A.26/J.116 – Initialisation and provisioning signalling

A.5.5.3.1 <MAC> Provisioning channel message (Broadcast downstream)

The <MAC> PROVISIONING CHANNEL MESSAGE is sent by the INA to direct the NIU to the proper OOB frequency where provisioning is performed. The format of the message is shown in Table A.18.

Table A.18/J.116 – Provisioning channel message format

Provisioning_Channel_Message(){	**Bits**	**Bytes**	**Bit Number/Description**
Provisioning_Channel_Control_Field	8	1	
reserved	7		7-1:
provisioning_frequency_included	1		0: {no=0, yes=1}
if (provisioning_frequency_included) {			
Provisioning_Frequency	(32)	(4)	
DownStream_Type	8	1	
}			
}			

Provisioning Channel Control Field

Provisioning_Channel_Control_Field is used to specify the downstream frequency where the NIU will be provisioned.

Provisioning frequency included

Provisioning_frequency_included is a Boolean, when set, indicates that a downstream OOB IF frequency is specified that the NIU should tune to begin the provisioning process. When cleared, indicates that the current downstream IF frequency is the provisioning frequency.

Provisioning frequency

Provisioning_frequency is a 32-bit unsigned integer representing the OOB IF frequency in which NIU provisioning occurs. The unit of measure is Hz.

Downstream Type

DownStream_Type is an 8-bit enumerated type indicating the modulation format for the down stream connection. {reserved, reserved, QPSK_3.088, 3..255 reserved}

A.5.5.3.2 <MAC> Default configuration message (Broadcast downstream)

The <MAC> DEFAULT CONFIGURATION MESSAGE is sent by the INA to the NIU. The message provides default parameter and configuration information to the NIU. The format of the message is shown in Table A.19.

Table A.19/J.116 – Default configuration message structure

Default_Configuration_Message(){	Bits	Bytes	Bit Number/Description
Sign_On_Incr_Pwr_Retry_Count	**8**	**1**	
Service_Channel_Frequency	**32**	**4**	
Service_Channel_Control_Field	**8**	**1**	
MAC_Flag_Set	5		7-3
Service_Channel	3		2-0
Backup_Service_Channel_Frequency	**32**	**4**	
Backup_Service_Channel_Control_Field	**8**	**1**	
Backup_MAC_FlagSet	5		7-3
Backup_Service_Channel	3		2-0
Service_Channel_Frame_Length [reserved]	**16**	**2**	unused here
Service_Channel_Last_Slot	**16**	**2**	
Max_Power_Level	**8**	**1**	
Min_Power_Level	**8**	**1**	
Upstream_Transmission_Rate	**3**	**1**	**unused here**

Sign-On Increment Power Retry Count

Sign_On_Incr_Pwr_Retry_ Count is an 8-bit unsigned integer representing the number of attempts the NIU should try to enter the system at the same power level before incrementing its power level by steps of 0.5 dB.

Service Channel frequency

Service_Channel_frequency is a 32-bit unsigned integer representing the upstream IF frequency assigned to the service channel. The unit of measure is in Hz. This channel is identified as channel #0 for collision indications.

MAC_Flag_Set is a 5-bit field representing the MAC Flag set assigned to the service channel. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 to 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 to 15. This parameter represents the first of two successively assigned flag sets. This flag set indicates the x value the channel x associated to Rxa, Rxb, Rxc in the reception indicator fields.

Service_Channel is a 3-bit field which defines the channel assigned to the Service_Channel_Frequency.

Backup Service Channel frequency

Backup_Service_Channel_frequency is a 32-bit unsigned integer representing the upstream IF frequency assigned to the backup service channel. The backup service channel is used when entry on the primary service channel fails. The unit of measure is in Hz. This channel is identified as channel #1 for collision indications.

Backup_MAC_Flag_Set is a 5-bit field representing the MAC Flag set assigned to the backup service channel. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 to 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 to 15. In the case of a 3.088 Mbit/s upstream channel, this parameter represents the first of two successively assigned flag sets.

Backup_Service_Channel is a 3-bit field which defines the channel assigned to the Backup_Service_Channel_Frequency.

Service_Channel_Frame_Length [reserved]

Unused in this version.

Service Channel Last Slot

Service_Channel_Last_Slot is a 16-bit unsigned integer representing the last slot in the Service Channel frame that is used for contention based access. This number represents the largest slot value of the NIU slots counter ($n \times 3 \times m$, where n is defined in A.5.4.3).

Maximum Power Level

MAX_Power_Level is an 8-bit unsigned integer representing the maximum power the NIU shall be allowed to use to transmit upstream. The unit of measure is in dBμV (RMS) on 75 Ω.

Minimum Power Level

MIN_Power_Level is an 8-bit unsigned integer representing the minimum power the NIU shall be allowed to use to transmit upstream. The unit of measure is in dBμV (RMS) on 75 Ω.

Upstream Transmission Rate

Upstream_Transmission_Rate is a 3-bit enumerated type that indicates the upstream transmission rate.

```
enum Upstream_Transmission_Rate { _reserved, reserved, Upstream_3-088Mb/s, reserved..7};
```

A.5.5.4 Sign-On and Calibration

The NIU shall sign on via the Sign-On Procedure. The signalling flow for Sign-On is described below.

– The NIU shall tune to the downstream Provisioning channel and the upstream service channel with the information provided in the Initialisation and Provisioning sequence.
– The NIU shall await the **<MAC> Sign-On Message** from the INA Entity. The NIU shall utilise Contention based entry on the service channel to access the network.
– Upon receiving the **<MAC> Sign-On Message**, the NIU shall respond with the **<MAC> Sign-On Response Message.** The **Sign-On** Response Message shall be transmitted on a Ranging Control Slot.
– The INA, upon receiving the **Sign-On** Response Message shall validate the NIU and send the **<MAC> Ranging and Power Calibration Message**.

– The NIU shall respond to the <MAC> Ranging and Power Calibration Message with the <MAC> Ranging and Power Calibration Response Message. The <MAC> Ranging and Power Calibration Response Message shall be transmitted on a Ranging Control Slot.

– The INA shall send the **<MAC> Initialisation Complete Message** when the NIU is calibrated. The NIU is assumed to be calibrated if the message arrives within a window of 1.5 symbols (upstream rate) and a power within a window of 1.5 dB from their optimal value. See Figure A.27.

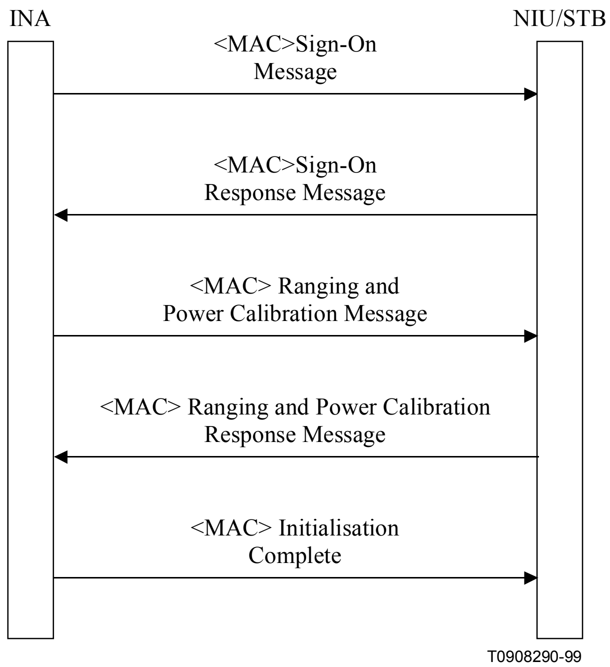


Figure A.27/J.116 – Ranging and calibration signalling

The state diagram in Figure A.28 details the procedure described above.

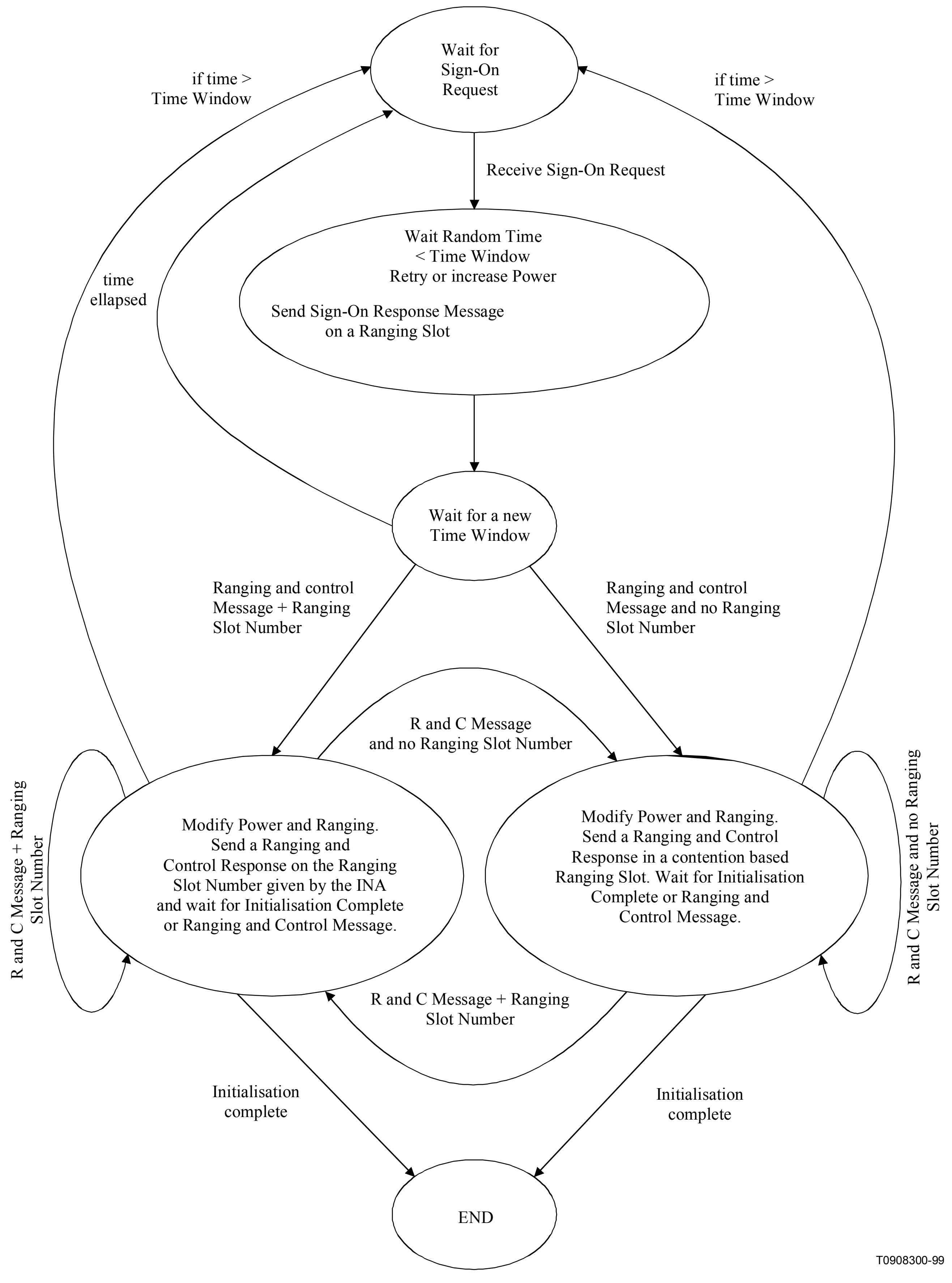


Figure A.28/J.116 – State diagram for ranging and calibration

A.5.5.4.1 <MAC> Sign-On Request message (Broadcast downstream)

The <MAC> SIGN-ON REQUEST message is issued periodically by the INA to allow a NIU to indicate its presence in the network. The format of this subcommand is shown in Table A.20.

Table A.20/J.116 – Sign-On Message structure

Sign-On_Request_Message(){	Bits	Bytes	Bit Number/Description
Sign-On_Control_Field	8	1	
Reserved	7		7-1
Address_Filter_Params_Included	1		0: {no, yes}
Response_Collection_Time_Window	16	2	
if (Sign-On_Control_Field= Address_Filter_Params_Included {			
Address_Position_Mask	(8)	(1)	
Address_Comparison_Value	(8)	(1)	
}			
}			

Sign-On Control Field

Sign-On_Control_Field specifies what parameters are included in the SIGN-ON REQUEST.

Address filter parameters included

address_filter_params_included is a Boolean, when set, indicates that the NIU should respond to the SIGN-ON REQUEST only if its address matches the filter requirements specified in the message.

Response Collection Time Window

Response_Collection_Time_Window is a 16-bit unsigned integer that specifies the duration of time the NIU has to respond to the SIGN-ON REQUEST. The unit of measure is the millisecond (ms).

Address Position Mask

Address_Position_Mask is an 8-bit unsigned integer that indicates the bit positions in the NIU MAC address that are used for address filtering comparison. The bit positions are comprised between bit number 2^{Mask} and $2^{Mask} + 7$.

Mask = 0 corresponds to the 8 LSBs of the address, i.e. it represents the number of bits shifted to the left. The maximum value is 40.

Address Comparison Value

Address_Comparison_Value is an 8-bit unsigned integer that specifies the value that the NIU should use for MAC address comparison.

See Figure A.29.

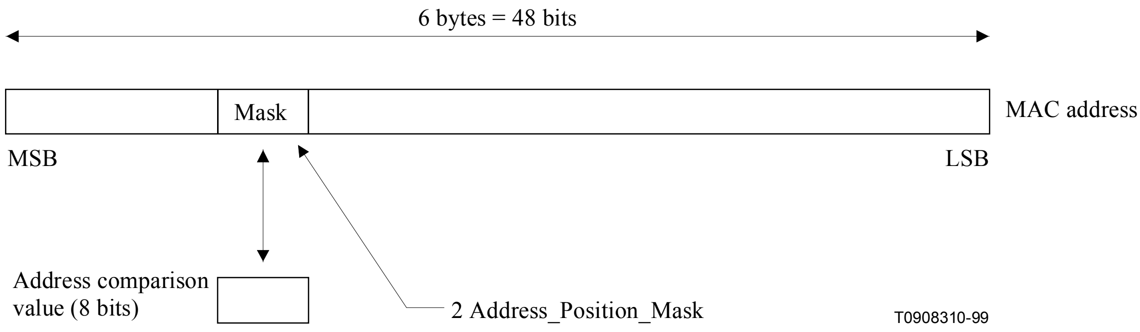


Figure A.29/J.116 – Position of mask in MAC address

A.5.5.4.2 <MAC> Sign-On Response Message (Upstream Contention Ranging)

The <MAC> Sign-On Response Message is sent by the NIU in response to the <MAC> Sign-On Request Message issued by the INA Entity. The NIU shall wait for a random time less than Response_Collection_Time_Window to send this message. See Table A.21.

Table A.21/J.116 – Sign-On response message structure

Sign-On_Response_Message(){	Bits	Bytes	Bit Number/Description
[reserved]	32	4	
[reserved]	16	2	
Retry_Count	8	1	
}			

Retry Count

Retry_Count is an 8-bit unsigned integer that indicates the number of transmissions of the <MAC> Sign-On Response. This field is always included in the response to the <MAC> Sign-On Request.

A.5.5.4.3 <MAC> Range and Power Calibration Message (Singlecast downstream)

The <MAC> RANGE AND POWER CALIBRATION MESSAGE is sent by the INA to the NIU to adjust the power level or time offset the NIU is using for upstream transmission. The format of this message is shown in Table A.22.

Table A.22/J.116 – Range and Power Calibration Message structure

Range_and_Power_Calibration_Message(){	Bits	Bytes	Bit Number/Description
Range_Power_Control_Field	8	1	
reserved	5		7-3:
ranging_slot_included	1		2: {no, yes}
time_adjustment_included	1		1: {no, yes}
power_adjustment_included	1		0: {no, yes}
if (range_power_control_field == time_adjustment_included) {			
Time_Offset_Value	(16)	(2)	
}			
if (range_power_control_field == power_adjustment_included) {			
Power_Control_Setting	(8)	(1)	
}			
if (range_power_control_field == ranging_slot_included) {			
Ranging_Slot_Number	(16)	(2)	
}			
if (range_frequency_control-field = = frequency_adjustment_included) {			
Frequency_Offset_Value	(32)	(4)	
}			

Range and Power Control Field

Range_Power_Control_Field specifies which Range and Power Control parameters are included in the message.

Time adjustment included

time_adjustment_included is a Boolean, when set, indicates that a relative time offset value is included that the NIU should use to adjust its upstream fixed rate based reference.

Power adjust included

power_adjust_included is a Boolean, when set, indicates that a relative Power Control setting is included in the message.

Ranging Slot Included

Ranging_Slot_Included is a Boolean, when set, indicates the calibration slot available.

Time Offset Value

Time_Offset_Value is a 16-bit short integer representing a relative offset of the upstream transmission timing.

A negative value indicates an adjustment forward in time. A positive value indicates an adjustment back in time. The unit of measure is 100 ns. (The NIU will adjust approximately its time offset to the closest value indicated by the Time_Offset_Value parameter, which implies that no extra clock is needed to adjust to the correct offset.)

Frequency Offset Value

Frequency_Offset_Value is a 32-bit signed integer representing the upstream carrier offset frequency compared to the centre IF frequency. The unit measure is in Hz.

Power Control Setting

Power_Control_Setting is an 8-bit signed integer to be used to set the new power level of the NIU. (A positive value represents an increase of the output power level.)

New output_power_level = current output_power_level + power_control_setting × 0.5 dB

Ranging Slot Number

Ranging_Slot_Number is a 16-bit unsigned integer that represents the reserved access Slot Number assigned for Ranging the NIU.

A.5.5.4.4 <MAC> Ranging and Power Calibration Response Message (Upstream reserved or contention Ranging)

The <MAC> RANGING AND POWER CALIBRATION RESPONSE Message is sent by the NIU to the INA in response to the <MAC> RANGING AND POWER CALIBRATION MESSAGE. The format of the message is shown in Table A.23.

Table A.23/J.116 – Range Response Message format

Ranging_Power_Response_Message(){	Bits	Bytes	Bit Number/Description
Power_Control_Setting	8	1	
}			

Power Control Setting

Power_Control_Setting is an 8-bit signed integer representing the upstream power level used by the NIU. It is a copy of the power control setting parameter received from INA.

A.5.5.4.5 <MAC> Initialisation complete message (singlecast downstream)

This message has no message body. It indicates the end of the MAC Sign-On and Provisioning procedure.

A.5.5.5 Default connection establishment

Once a NIU has completed the Calibration State, it shall enter the Connection State. A low bit rate permanent connection is assigned to a NIU by the INA. After the initial calibration procedure, the INA provides a Default Connection to the NIU that the NIU shall utilise to communicate to the network. The message flow for such Connection Establishment is shown below.

1) After Initialisation, Provisioning and Sign-On procedures are complete, the INA shall assign a default upstream and downstream connection to the NIU. This connection can be assigned on any of the upstream channels except the upstream service channel ranging area. The INA shall assign the default connection by sending the **<MAC> Connect Message** to the NIU. This message shall contain the upstream connection parameters and downstream IF frequency on which the default connection is to reside.
2) The NIU, upon receiving the **<MAC> Connect Message** shall tune to the required upstream and downstream frequencies and send the **<MAC> Connect Response Message** confirming receipt of the message.

3) Upon receipt of the **<MAC> Connect Response Message**, the INA shall confirm the new connection to proceed by sending the **<MAC> Connect Confirm Message**. See Figure A.30.

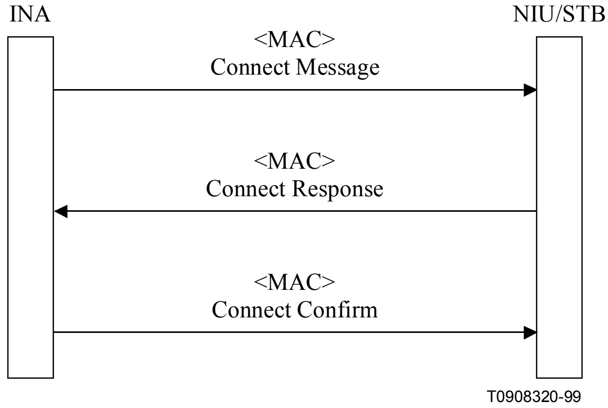


Figure A.30/J.116 – Connection signalling

A.5.5.5.1 <MAC> Connect message (Singlecast downstream)

See Table A.24.

Table A.24/J.116 – Connect message structure

Connect_Message (){	Bits	Bytes	Bit Number/Description
Connection_ID	32	4	
Session_Number	32	4	
Resource_Number	16	2	
Connection_Control_Field	8	1	
Descriptor_Type	3		
Upstream_Channel_Number	3		
MAC_Control_Parameters	2		
Frame_Length	(16)	(2)	
Maximum_Contention_Access_Message_Length	(8)	(1)	
Maximum_Reservation_Access_Message_Length	(8)	(1)	
if(Descriptor_Type == DS_ATM_CBD){			
Downstream_ATM_CBD()	(64)	(8)	
}			
if(Descriptor_Type == DS_CBD_MPEG){			
Downstream_CBD_MPEG()	(48)	(6)	
}			
if(Descriptor_Type == US_ATM_Included){			
Upstream_ATM_CBD()	(64)	(8)	
}			
if(MAC_Control_Params == slot_list_assignment){			Fixed Rate Access

Table A.24/J.116 – Connect message structure *(concluded)*

Connect_Message (){	Bits	Bytes	Bit Number/Description
Number_Slots_Defined	(8)	(1)	
for (i=0;i<Number_Slots_Assigned; i++{			
Slot_Number	(16)	(2)	
}			
}			
if (MAC_Control_Params == cyclic_Assignment){			Fixed Rate Access
Fixedrate_Start	(16)	(2)	
Fixedrate_Dist	(16)	(2)	
Fixedrate_End	(16)	(2)	
}			

Connection ID

Connection_ID is a 32-bit unsigned integer representing a connection Identifier for the NIU dynamic connection.

Session Number

Session_Number is a 32-bit unsigned integer representing the session that the connection parameters are associated.

Resource Number

Resource_Number is a 16-bit unsigned integer providing a unique number to the resource defined in the message.

Connection Control Field

Connection_Control_Field is an 8-bit unsigned integer that defines parameters and control for Descriptor_Type, Upstream_Channel_Number and MAC_Control_Parameters. This is partitioned across the 8 bits as shown in Table A.25.

Table A.25/J.116 – Connection control field substructure

Bit 7	6	5	4	3	2	1	0
Descriptor_Type			Upstream_Channel_Number			MAC_Ctrl_Params	

Descriptor Type

Descriptor_Type is a 3-bit unsigned integer that represents the connection descriptors present within the message. The values are defined in Table A.26.

Table A.26/J.116 – Descriptor type substructure

Bit Number	Definition
7	When set indicates that upstream ATM Descriptor is present in the message
6	When set indicates that downstream MPEG Descriptor is present in the message
5	When set indicates that downstream ATM Descriptor is present in the message

Upstream Channel Number

Upstream_Channel_Number is a 3-bit unsigned integer that provides an identifier for the upstream channel.

MAC Control Parameters

MAC_Control_Parameters is a 2-bit unsigned integer that indicates the type of upstream resources assigned in the connection. See Table A.27.

Table A.27/J.116 – Control parameter substructure

MAC_Control_Parameters	Definition
10	Indicates a slot list is included
01	Indicates a cyclical assignment
00	Indicates contention based access only
11	[Reserved for future definition by ITU-T]

Frame length

Frame_length – This 16-bit unsigned number represents the number of successive slots in the contentionless access region that associated with each contentionless slot assignment. In the slot_list method of allocating slots, it represents the number of successive slots associated with each element in the list. In the cyclic method of allocating slots, it represents the number of successive slots associated with the Fixedrate_Start_slot and those which are multiples of Fixedrate_Distance from the Fixedrate_Start_slot within the Fixed rate access region.

Maximum contention access message length

Maximum_contention_access_message_length is an 8-bit number representing the maximum length of a message in ATM sized cells that may be transmitted using contention access. Any message greater than this should use reservation access.

Maximum reservation access message length

Maximum_reservation_access_message_length is an 8-bit number representing the maximum length of a message in ATM sized cells that may be transmitted using a single reservation access. Any message greater than this should be transmitted by making multiple reservation requests.

Downstream ATM connection block descriptor

See Table A.28.

Table A.28/J.116 – ATM connection block descriptor substructure

Downstream_ATM_CBD(){	Bits	Bytes	Bit Number/Description
Downstream_Frequency	32	4	
Downstream_VPI	8	1	
Downstream_VCI	16	2	
Downstream_Type	8	1	
}			

Downstream Frequency

Downstream_Frequency is a 32-bit unsigned integer representing the IF frequency where the connection resides. The unit of measure is in Hz.

Downstream Virtual Path Identifier (VPI)

Downstream_VPI is an 8-bit unsigned integer representing the ATM VPI that is used for downstream transmission over the dynamic connection.

Downstream Virtual Channel Identifier (VCI)

Downstream_VCI is a 16-bit unsigned integer representing the ATM VCI that is used for downstream transmission over the dynamic connection.

DownStream_Type

DownStream_Type is an 8-bit enumerated type indicating the modulation format for the downstream connection. {QPSK_in_band, reserved, QPSK_3.088, 3..255 reserved}.

Downstream MPEG connection block descriptor

See Table A.29.

Table A.29/J.116 – Downstream_CBD_MPEG substructure

Downstream_CBD_MPEG(){	Bits	Bytes	Bit Number/Description
Downstream_Frequency	32	4	
Program Number	16	2	
}			

Downstream Frequency

Downstream_Frequency is a 32-bit unsigned integer representing the IF frequency where the connection resides. The unit of measure is in Hz.

Program Number

Program_Number is a 16-bit unsigned integer uniquely referencing the downstream virtual connection assignment.

Upstream ATM connection block descriptor

See Table A.30.

Table A.30/J.116 – Upstream_CBD substructure

Upstream_ATM_CBD	Bits	Bytes	Bit Number/Description
Upstream_Frequency	32	4	
Upstream_VPI	8	1	
Upstream_VCI	16	2	
MAC_Flag_Set	5	1	7:3
Upstream_Rate	3		2:0
}			

Upstream Frequency

Upstream_Frequency is a 32-bit unsigned integer representing the channel assigned to the connection. The unit of measure is in Hz.

Upstream VPI

Upstream_VPI is an 8-bit unsigned integer representing the ATM VPI that is used for upstream transmission over the dynamic connection.

Upstream VCI

Upstream_VCI is a 16-bit unsigned integer representing the ATM VCI that is used for upstream transmission over the dynamic connection.

MAC_Flag_Set

MAC_Flag_Set is a 5-bit field representing the MAC Flag set assigned to the connection. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 to 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 to 15. In the case of a 3.088 Mbit/s upstream channel, this parameter represents the first of two successively assigned flag sets.

Upstream_Rate

Upstream_Rate is a 3-bit enumerated type indicating the data rate for the upstream connection. {Reserved, reserved, Upstream_3.088M,..7, reserved}.

Number of Slots Defined

Number_Slots_Defined is an 8-bit unsigned integer that represents the number of slot assignments contained in the message. The unit of measure is slots.

Slot Number

Slot_Number is a 16-bit unsigned integer that represents the fixed rate based slot number assigned to the NIU.

Fixed rate Start

Fixedrate_Start – This 16-bit unsigned number represents the starting slot within the fixed rate access region that is assigned to the NIU. The NIU may use the next Frame_length slots of the fixed rate access regions.

Fixed rate Distance

Fixedrate_Distance – This 16-bit unsigned number represents the distance in slots between additional slots assigned to the NIU. The NIU is assigned all slots that are a multiple of Fixedrate_Distance from the Fixedrate_Start_slot which do not exceed Fixedrate_End_slot. The NIU may use the next Frame_length slots of the fixed rate access regions from each of these additional slots.

Fixed rate End

Fixedrate_End – This 16-bit unsigned number indicates the last slot that may be used for fixed rate access. The slots assigned to the NIU, as determined by using the Fixedrate_Start_slot and Fixedrate_Distance, cannot exceed this number.

A.5.5.5.2 <MAC> Connect response (upstream contention, reserved or fixed rate access)

The <MAC> CONNECT RESPONSE MESSAGE is sent to the INA from the NIU in response to the <MAC> CONNECT MESSAGE. The message shall be transmitted on the upstream IF frequency specified in the <MAC> CONNECT MESSAGE. See Table A.31.

Table A.31/J.116 – Connect response message structure

Connect_Response(){	Bits	Bytes	Bit Number/Description
Connection_ID	32	4	
}			

Connection ID

Connection_ID is a 32-bit unsigned integer representing a global connection Identifier for the NIU Dynamic Connection.

A.5.5.5.3 <MAC> Connect confirm (singlecast downstream)

The <MAC> Connect Confirm message is sent from the INA to the NIU. Its usage is recommended when INA validation of new connection is required. See Table A.32.

Table A.32/J.116 – Connect confirm message structure

Connect_Confirm(){	Bits	Bytes	Bit Number/Description
Connection_ID	32	4	
}			

Connection ID

Connection_ID is a 32-bit unsigned integer representing a global connection Identifier for the NIU Dynamic Connection.

A.5.5.6 Data connections

A connection is initiated by the INA using the <MAC> Connect Message explained in A.5.5.5.1. This message is either used to immediately assign time slots for a fixed rate connection or just to assign a connection ID and related parameters without time slot assignment. In particular, for reservation or contention access, no time slots are assigned in the Connect Message, but the connection ID shall be used in requests for slots by the NIU.

Connection assignment

The INA can assign other connections by using the **<MAC> Connect message** described previously. The NIU cannot request a connection, it shall be initiated by higher layers.

Connection release

This clause defines the MAC signalling requirements for connection release. Figure A.31 displays the signalling flow for releasing a connection. The NIU cannot release a connection, this shall be initiated by higher layers. This message is thus initiated by the INA only.

1) Upon receiving the **<MAC> Release Message** from the INA, the NIU shall teardown the upstream connection established.
2) Upon teardown of the upstream connection, the NIU shall send the **<MAC> Release Response Message** on the default upstream channel.

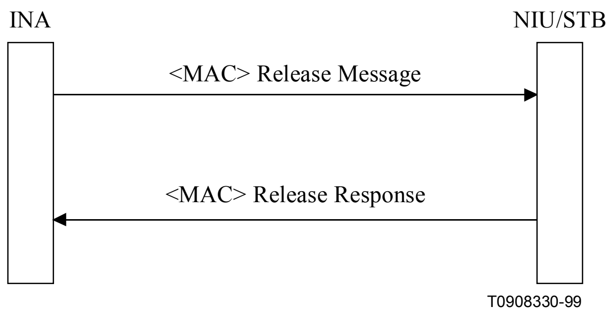


Figure A.31/J.116 – Connection release signalling

<MAC> Release Message (Singlecast downstream)

The <MAC> Release Message is sent from the INA to the NIU to terminate a previously established connection. See Table A.33.

Table A.33/J.116 – Release message structure

Release_Message(){	Bits	Bytes	Bit Number/Description
Number_of_Connections	8	1	
for(i=0;i<Number_of_Connections;i++){			
Connection_ID }	32	4	
}			

Connection ID

Connection_ID is a 32-bit unsigned integer representing a global connection identifier for the NIU dynamic connection.

<MAC> Release Response (Upstream contention, reserved or fixed rate)

The <MAC> RELEASE RESPONSE MESSAGE is sent by the NIU to the INA to acknowledge the release of a connection. The format of the message is shown in Table A.34.

Table A.34/J.116 – Release response message structure

Release_Response_Message (){	Bits	Bytes	Bit Number/Description
Connection_ID	32	4	
}			

Connection ID

Connection_ID is a 32-bit unsigned integer representing the global connection Identifier used by the NIU for this connection.

A.5.5.6.1 Fixed rate access

Fixed rate access is provided by the INA using the <MAC> Connect Message.

A.5.5.6.2 Contention based access

The NIU shall use contention based slots specified by the slot boundary definition fields (Rx) to transmit contention based messages (see A.5.3). The format of contention based MAC messages is described by the MAC message format (see A.5.5.2.3).

A.5.5.6.3 Reservation access

This clause defines the MAC signalling requirements for reservation access. Figure A.32 shows the signalling flow for reserving an access.

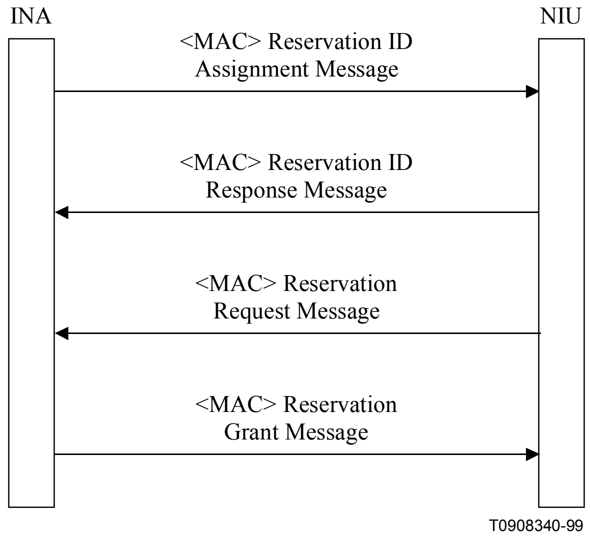


Figure A.32/J.116 – Reservation access signalling

1) The NIU shall wait for a <MAC> Reservation ID Assignment Message from the INA before it can request reservation access. It shall respond with a <MAC> Reservation ID response Message.
2) At any time when needed after receiving the reservation ID, the NIU can request a certain number of slots to the INA using the <MAC> Reservation Request Message.
3) The INA shall respond to that message using the <MAC> Reservation Grant Message.
4) If the NIU has not received the <MAC> Reservation Grant Message before the Grant_Protocol_Timeout, it shall send a <MAC> Reservation Status Request to the INA. This leads back to 3).

<MAC> Reservation ID assignment message (singlecast downstream)

The <MAC> Reservation ID Assignment Message is used to assign the NIU a Reservation_ID. The NIU identifies its entry in the Reservation_grant_message by comparing the Reservation_ID assigned to it by the Reservation_ID_assignment_message and the entries in the Reservation_Grant_message.

The format of the message is given in Table A.35.

Table A.35/J.116 – Reservation ID assignment message structure

Reservation_ID_assignment_Message (){	Bits	Bytes	Bit Number/Description
Connection_ID	32	4	
Reservation_ID	16	2	
Grant_protocol_timeout	16	2	
}			

Connection ID

Connection_ID is a 32-bit unsigned integer representing a global connection identifier for the NIU dynamic connection.

Reservation_ID

Reservation_ID is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Grant_protocol_timeout

Grant_protocol_timeout is a 16-bit unsigned number representing the time in milliseconds that the NIU should wait before verifying the status of pending grants. This parameter specifies the time that the NIU should wait after receiving the last Reservation_grant_message, with an entry addressed to the NIU, before initiating a reservation status request. If the NIU has pending grants and the timeout occurs, it should send the Reservation_status_request message to the INA. The INA will respond with the Reservation_grant_message (probably without granting any slots) to inform the NIU of any remaining slots left to be granted. This allows the NIU to correct any problems should they exist such as issuing an additional request for slots or waiting patiently for additional grants.

<MAC> Reservation ID Response Message

The MAC reservation ID response Message is used to acknowledge the receipt of the <MAC> Reservation_ID_Assignment message. The format of the message is given in Table A.36.

Table A.36/J.116 – Reservation ID Response Message

Reservation_ID_Response_Message (){	Bits	Bytes	Bit Number/Description
Connection_ID	32	4	
Reservation_ID	16	2	
}			

Connection_ID

Connection_ID is a 32-bit unsigned integer representing a global connection identifier for the NIU/STB dynamic connection.

Reservation_ID

Reservation_ID is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the NIU/STB to identify the appropriate Reservation_Grant_Messages.

<MAC> Reservation request message (upstream contention, fixed rate or reserved)

See Table A.37.

Table A.37/J.116 – Reservation request message structure

Reservation_Request_message (){	Bits	Bytes	Bit Number/Description
Reservation_ID	16	2	
Reservation_request_slot_count	8	1	
}			

This message is sent from the NIU to the INA.

Reservation_ID

Reservation_ID is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Reservation Request Slot Count

Reservation_request_slot_count is an 8-bit unsigned number representing the number of slots requested by the NIU. This is the number of sequential slots that will be allocated in the reservation region of the upstream channel. The INA will respond with the Reservation_Grant message granting the request.

<MAC> Reservation grant message (broadcast downstream)

The <MAC> RESERVATION GRANT MESSAGE is used to indicate to the NIU which slots have been allocated in response to the Reservation Request message. The NIU identifies its entry in the Reservation_grant_message by comparing the Reservation_ID assigned to it by the Reservation_ID_assignment_message and the entries in the Reservation_Grant_message.

The format of the message is given in Table A.38.

Table A.38/J.116 – Reservation grant message structure

Reservation_grant_message (){	Bits	Bit Number/Description
Reference_slot	16	
Number_grants	8	
for (I=1; I<=Number_grants; I++){		
Reservation_ID	16	
Grant_Slot_count	4	
Remaining_slot_count	5	
Grant_control	2	
Grant_slot_offset	5	
}		
}		

Reference_slot

Reference_slot is a 16-bit unsigned number indicating the reference point for the remaining parameters of this message. This represents a physical slot of the upstream channel. Since the upstream and downstream slots are not aligned, the INA shall send this message in a downstream slot such that it is received by the NIU before the Reference_slot exists on the upstream channel.

Number_grants

Number_grants is an 8-bit unsigned number representing the number of grants contained within this message.

Reservation_ID

Reservation_ID is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Grant_slot_count

Grant_slot_count is a 4-bit unsigned number representing the number of sequential slots currently granted for the upstream burst. Upon receipt of this message the NIU is assigned Grant_slot_count sequential slots in the reservation access region of the upstream channel starting at the position indicated by the Reference_slot and Grant_slot_offset values. A value of zero indicates that no slots are being granted. This would typically be the case in a response to a Reservation_status_request message.

Remaining_slot_count

Remaining_slot_count is a 5-bit unsigned number representing the remaining slots to be granted by the INA with subsequent grant messages. A value of 0x1f indicates that 31 or more slots will be made available in the future. A value of 0x0 indicates that no additional slots will be granted in the future and that the slots granted in this message represent the only remaining slots available for the connection. The NIU should monitor this count to determine if sufficient slots remain to satisfy current needs. Should additional slots be required because of lost grant messages or additional demand, additional slots should be requested using the Reservation_request_message. Additional Reservation_request_messages shall be sent only when the Remaining_slot_count is less than 15. To minimise contention on the upstream channel, the Reservation_request_message may be sent in one of the slots granted by the Reservation_Grant_Message.

Grant_slot_offset

Grant_slot_offset is a 5-bit unsigned number representing the starting slot to be used for the upstream burst. This number is added to the Reference slot to determine the actual physical slot. Upon receipt of this message the NIU is assigned Grant_slot_count sequential slots in the reservation access region of the upstream channel.

<MAC> Reservation Status Request (Upstream contention, fixed rate or reserved)

The <MAC> RESERVATION STATUS REQUEST Message is used to determine the status of the outstanding grants to be assigned by the INA. This message is only sent after the Grant protocol time-out is exceeded. The INA will respond with the Reservation_grant_message (possibly without granting any slots) to inform the NIU of any remaining slots left to be granted. This allows the NIU to correct any problems should they exist such as issuing an additional request for slots or waiting for additional grants.

The format of the message is given in Table A.39.

Table A.39/J.116 – Reservation status request message structure

Reservation_Status_Request_Message (){	Bits	Bytes	Bit Number/Description
Reservation_ID	16	2	
Remaining_request_slot_count	8	1	
}			

Reservation_ID

Reservation_ID is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Remaining_request_slot_count

Remaining_request_slot_count is an 8-bit unsigned number representing the number of slots that the NIU is expecting to be granted.

A.5.5.7 MAC link management

The MAC link management tasks provide continuous monitoring and optimisation of upstream resources. These functions include:

– power and timing management;

– fixed rate allocation management;

– channel error management.

A.5.5.7.1 Power and timing management

Power and timing management shall provide continuous monitoring of upstream transmission from the NIU. The **<MAC> Ranging and Power Calibration Message** is used to maintain a NIU within predefined thresholds of power and time.

The upstream burst demodulator shall continuously monitor the upstream burst transmissions from an NIU. Upon detection of an NIU outside the predefined range, the INA shall send the **<MAC> Ranging and Power Calibration Message** to the NIU.

A.5.5.7.2 TDMA allocation management

To ensure optimum assignment of TDMA resources, the INA shall ensure the upstream allocation of TDMA resources for various connections remain intact when allocating resources to a new connection. However, in the event that reconfiguration is required to minimise fragmentation of resources, then the INA shall dynamically reconfigure the upstream TDMA assignments to a NIU or group of NIUs. The **<MAC> Reprovision Message** is utilised to change previously established connection parameters.

<MAC> Reprovision message (singlecast downstream)

The <MAC> REPROVISION MESSAGE is sent by the INA to the NIU to reassign upstream resources (maintaining the originally requested QoS parameters at the establishment of the connection). This message is intended for fixed rate based channel maintenance by the INA to redistribute or reassign resources allocated to a NIU. See Table A.40.

Table A.40/J.116 – Reprovision message structure

Reprovision_Message (){	Bits	Bytes	Bit Number/Description
Reprovision_Control_Field	8	1	
Reserved	2		7-6
New_Downstream_IB_Frequency	1		5: {no, yes}
New_Downstream_OOB_Frequency	1		4: {no, yes}
New_Upstream_Frequency_Included	1		3: {no, yes}
New_Frame_Length_Included	1		2: {no, yes}
New_Cyclical_Assignment_Included	1		1: {no, yes}
New_Slot_List_Included	1		0: {no, yes}
if (Reprovision_Control_Field= New_Downstream_OOB_Frequency)			
New_Downstream_IB_Frequency	(32)	(4)	
if (Reprovision_Control_Field= New_Downstream_OOB_Frequency)			
New_Downstream_OOB_Frequency	(32)	(4)	
DownStream_Type	8	1	
New_Downstream_OOB_Frequency	(32)	(4)	
if (Reprovision_Control_Field= New_Frequency_Included)			
New_Upstream_Frequency	(32)	(4)	
New_Upstream_Channel_Number	3	1	**7:5**
reserved	2		**4:3**
Upstream_Rate	3		**2:0**
MAC_Flag_Set	5	1	**7:3**
Reserved	3		**2:0**
New_Upstream_Frequency	(32)	(4)	
if (Connection_Control_Field= New_Frame_Size_Included)			
New_Frame_Length	(16)	(2)	9-0: Unsigned
if (Reprovision_Control_Field= New_Slot_List){			
Number_of_Connections	(8)	(1)	
for(i=0;i<Number_of_Connections;i++){			
Connection_ID	(32)	(1)	
if (Reprovision_Control_Field == new_slot_list_included){			**Fixed Rate Access**
Number_Slots_Defined	(8)	(1)	
for(i=0;i<Number_Slots_Assigned;i++){			
Slot_Number	(16)	(2)	
}			

Table A.40/J.116 – Reprovision message structure *(concluded)*

Reprovision_Message (){	Bits	Bytes	Bit Number/Description
if (Reprovision_Control_Field == new_cyclic_Assignment_included){			**Fixed Rate Access**
Fixedrate_Start	(16)	(2)	
Fixedrate_Dist	(16)	(2)	
Fixedrate_End	(16)	(2)	
}			

Reprovision Control Field

Reprovision_Control_Field specifies what modifications to upstream resources are included.

New Downstream OOB frequency

New_Upstream_OOB_Frequency is a Boolean that indicates that a new downstream OOB IF frequency is specified in the message.

New Downstream IB frequency

New_Upstream_IB_Frequency is a Boolean that indicates that a new downstream IB IF frequency is specified in the message.

New Upstream frequency Included

New_Upstream_Frequency_Include is a Boolean that indicates that a new upstream IF frequency is specified in the message.

New Frame Length Included

New_Frame_Length_Include is a Boolean that indicates that a new upstream frame is specified in the message.

New Slot List Included

New_Slot_List_Include is a Boolean that indicates that a new slot list is specified in the message.

New Cyclical Assignment Included

New_Cyclical_Assignment_Include is a Boolean that indicates that a new cyclical assignment is specified in the message.

New Downstream Frequency

New_Downstream_IB_Frequency is a 32-bit unsigned integer representing the reassigned downstream IB carrier centre frequency. The unit of measure is Hz.

New Downstream OOB Frequency

New_Downstream_OOB_Frequency is a 32-bit unsigned integer representing the reassigned downstream OOB carrier centre frequency. The unit of measure is Hz.

DownStream_Type is an 8-bit enumerated type indicating the modulation format for the down stream connection. {reserved, reserved, QPSK_3.088, 3..255 reserved}.

New Upstream Frequency

New_Upstream_Frequency is a 32-bit unsigned integer representing the reassigned upstream carrier centre IF frequency. The unit of measure is Hz.

UpstreamStream_Rate is a 3-bit enumerated type indicating the data rate for the upstream connection. {Reserved, Reserved, Upstream_3.088M, 3..7 reserved}.

MAC_Flag_Set is a 5-bit field representing the MAC Flag set assigned to the connection. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 to 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 to 15. This parameter represents the first of two successively assigned flag sets.

New Frame Length

New_Frame_Length is a 16-bit unsigned integer representing the size of the reassigned upstream Fixed rate based frame. The unit of measure is in slots.

Number of Slots Defined

Number_Slots_Defined is an 8-bit unsigned integer that represents the number of slot assignments contained in the message. The unit of measure is slots.

Slot Number

Slot_Number is a 16-bit unsigned integer that represents the fixed rate based slot number assigned to the NIU.

A.5.5.7.3 Channel error management

During periods of connection inactivity, the NIU shall enter an idle mode. Idle mode is characterised by periodic transmission by the NIU of a **<MAC> Idle Message**. The idle mode transmission shall occur at a periodic rate sufficient for the INA to establish Packet Error Rate statistics.

<MAC> Idle Message (Upstream fixed rate or reserved)

The **<MAC> Idle Message** is sent by the NIU within the STB to the INA at predefined intervals (between 1 and 10 minutes) when upstream connection buffers are empty. See Table A.41.

Table A.41/J.116 – Idle message structure

Idle_Message(){	Bits	Bytes	Bit Number/ Description
Idle_Sequence_Count	8	1	
Power_Control_Setting	8	1	
}			

Idle Sequence Count

Idle_Sequence_Count is an 8-bit unsigned integer representing the count of <MAC> IDLE MESSAGES transmitted while the NIU is Idle.

Power Control Setting

Power_Control_Setting is an 8-bit unsigned integer representing the absolute power attenuation that the NIU is using for upstream transmission.

A.5.5.7.4 Link management messages

<MAC> Transmission control message (singlecast or broadcast downstream)

The <MAC> TRANSMISSION CONTROL MESSAGE is sent to the NIU from the INA to control several aspects of the upstream transmission. This includes stopping upstream transmission, re-enabling transmission from a NIU or group of NIUs and rapidly changing the upstream IF frequency being used by a NIU or group of NIUs. To identify a group of NIUs for switching frequencies, the <MAC> TRANSMISSION CONTROL MESSAGE is sent in broadcast mode with the Old_IF frequency included in the message. When broadcast with the Old_Frequency, the NIU shall compare its current IF frequency value to Old_Frequency. When unequal, the NIU shall switch to the new IF frequency specified in the message. When equal, the NIU shall ignore the new IF frequency and remain on its current channel. See Table A.42.

Table A.42/J.116 – Transmission control message structure

Transmission_Control_Message(){	**Bits**	**Bytes**	**Bit Number/Description**
Transmission_Control_Field	**8**		
reserved	3		7-5:
Stop_Upstream_Transmission	1		4: {no, yes}
Start_Upstream_Transmission	1		3: {no, yes}
Old_Frequency_Included	1		2: {no, yes}
Switch_Downstream_OOB_Frequency	1		1: {no, yes}
Switch_Upstream_Frequency	1		0: {no, yes}
if (Transmission_Control_Field== Switch_Upstream_Frequency && Old_Frequency_Included){			
Old_Upstream_Frequency	**(32)**	**(4)**	
}			
if (Transmission_Control_Field== Switch_Upstream_Frequency){			
New_Upstream_Frequency	**(32)**	**(4)**	
New_Upstream_Channel_Number	**3**	**1**	**7:5**
reserved	**2**		**4:3**
Upstream_Rate	**3**		**2:0**
MAC_Flag_Set	**5**	**1**	**7:3**
Reserved	**3**		**2:0**
New_Upstream_Frequency	**(32)**	**(4)**	
}			
if (Transmission_Control_Field== Switch_Downstream_OOB_Frequency && Old_Frequency_Included){			
Old_Downstream__OOB_Frequency	**(32)**	**(4)**	
}			
if (Transmission_Control_Field== Switch_Downstream_OOB_Frequency){			
New_Downstream_OOB_Frequency	**(32)**	**(4)**	
DownStream_Type	8	1	
}			
}			

Transmission Control Field

Transmission_Control_Field specifies the control being asserted on the upstream channel.

Stop Upstream Transmission

stop_upstream_transmission is a Boolean when set indicates that the NIU should halt its upstream transmission.

Start Upstream Transmission

start_upstream_transmission is a Boolean, when set, indicates that the Network Interface Unit should resume transmission on its upstream channel. The NIU shall respond to the ranging and power calibration message regardless of the setting of the start_upstream_transmission bit.

Old Frequency Included

Old_Frequency_Included is a Boolean, when set, indicates that the Old IF frequency value is included in the message and should be used to determine if a switch in IF frequency is necessary.

Switch Downstream OOB Frequency

switch_downstream_OOB_frequency is a Boolean, when set, indicates that a new downstream OOB IF frequency is included in the message.

Switch Upstream Frequency

switch_upstream_frequency is a Boolean, when set, indicates that a new upstream IF frequency is included in the message. Typically, the switch_upstream_frequency and the stop_upstream_transmission are set simultaneously to allow the NIU to stop transmission and change channel. This would be followed by the <MAC> TRANSMISSION CONTROL MESSAGE with the start_upstream_transmission bit set.

Old Upstream Frequency

Old_Upstream_Frequency is a 32-bit unsigned integer representing the IF frequency that should be used by the NIU to compare with its current IF frequency to determine if a change in channel is required.

New Upstream Frequency

New_Upstream_Frequency is a 32-bit unsigned integer representing the reassigned upstream IF carrier centre frequency. The unit of measure is Hz.

MAC_Flag_Set is a 5-bit field representing the MAC Flag set assigned to the connection. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 to 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 to 15. In the case of a 3.088 Mbit/s upstream channel, this parameter represents the first of two successively assigned flag sets.

Upstream Stream_Rate is a 3-bit enumerated byte indicating the data rate for the upstream connection. {reserved, reserved, Upstream_3.088M, 3..7 reserved}.

Old downstream OOB Frequency

Old_Downstream_OOB_Frequency is a 32-bit unsigned integer representing the IF frequency that should be used by the NIU to compare with its current IF frequency to determine if a change in channel is required.

New downstream OOB Frequency

New_Downstream_OOB_Frequency is a 32-bit unsigned integer representing the reassigned downstream OOB carrier centre IF frequency. The unit of measure is Hz.

DownStream_Type is an 8-bit enumerated type indicating the modulation format for the down stream connection. {reserved, reserved, QPSK_3.088, 3..255 reserved}.

Link Management Response Message (Upstream contention, fixed rate or reserved)

The <MAC> LINK MANAGEMENT RESPONSE MESSAGE is sent by the NIU to the INA to indicate reception and processing of the previously sent Link Management Message. The format of the message is shown in Table A.43.

Table A.43/J.116 – Link management acknowledge message format

Link_Management_Acknowledge(){	Bits	Bytes	Bit Number/Description
Link_Management_Msg_Number	16	2	
}			

Link Management Message Number

Link_Management_Msg_Number is a 16-bit unsigned integer representing the previously received link management message. The valid values for Link_Management_Msg_Number are shown in Table A.44.

Table A.44/J.116 – Link management message number

Message Name	Link_Management_Msg_Number
Transmission Control Message	Transmission Control Message Type Value
Reprovision Message	Reprovision Message Type Value

<MAC> Status Request Message (downstream Singlecast)

The STATUS REQUEST message is sent by the INA to the NIU to retrieve information about the NIU's health, connection information and error states. The INA can request either the address parameters, error information, connection parameters or physical layer parameters from the NIU. The INA can only request one parameter type at a time to a particular NIU. See Table A.45.

Table A.45/J.116 – Status request message structure

Status_Request(){	Bits	Bytes	Bit Number/Description
Status_Control_Field	8	1	
reserved	5		3-7:
Status_Type	3		0-2: {enum type}
}			

Status Control Field

Status_Control_Field is a 3-bit enumerated type that indicates the status information the NIU should return

enum Status_Control_Field {Address_Params, Error_Params, Connection_Params, Physical_Layer_Params, reserved4..7};

<MAC> Status response message (upstream contention, fixed rate or reserved)

The <MAC> STATUS RESPONSE MESSAGE is sent by the NIU in response to the <MAC> STATUS REQUEST MESSAGE issued by the INA. The contents of the information provided in this message will vary depending on the request made by the INA and the state of the NIU. The message shall be dissociated into separate messages if the resulting length of the message exceeds 40 bytes. See Table A.46.

Table A.46/J.116 – Status response message structure

Status_Response(){	Bits	Bytes	Bit Number/ Description
NIU_Status	32	4	
Response_Fields_Included	8	1	
reserved	4		4-7:
Address_Params_Included	1		3: {no, yes}
Error_Information_Included	1		2: {no, yes}
Connection_Params_Included	1		1: {no, yes}
Physical_Layer_Params_Included	1		0: {no, yes}
if (Response_Fields_Included == Address_Params_Included){			
NSAP_Address	(160)	(20)	
MAC_Address	(48)	(6)	
}			
if (Response_Fields_Included == Error_Information_Included){			
Number_Error_Codes_Included	(8)	(1)	
for(i=0;i<Number_Error_Codes_Included; i++){			
Error_Param_code	(8)	(1)	
Error_Param_Value	(16)	(2)	
}			
}			
if (Response_Fields_Included == Connection_Params_Included) {			
Number_of_Connections	(8)	(1)	
for(i=0;i<Number_of_Connections;i++){			
Connection_ID	(32)	(4)	
}			
if (Response_Fields_Included == Physical_Layer_Params_Included) {			
Power_Control_Setting	(8)	(1)	
Time_Offset_Value	(32)	(4)	
Upstream_Frequency	(32)	(4)	
Downstream_Frequency	(32)	(4)	
}			
}			

NIU Status

NIU_Status is a 32-bit unsigned integer that indicates the current state of the NIU.

NIU_Status {Calibration_Operation_Complete, Default_Connection_Established, Network_Address_Registered, reserved};

Response Fields Included

Response_Fields_Included is an 8-bit unsigned integer that indicates what parameters are contained in the upstream status response.

NSAP Address

NSAP_Address is a 20-byte address assigned to the NIU.

MAC Address

MAC_Address is a 6-byte address assigned to the NIU.

Number of Error Codes Included

Number_Error_Codes_Included is an 8-bit unsigned integer that indicates the number of error codes contained in the response.

Error Parameter Code

Error_Parameter_Code is an 8-bit unsigned integers representing the type of error reported by the NIU. See Table A.47.

Table A.47/J.116 – Error Parameter Code

Error Parameter Code Name	Error Parameter Code
Framing_Bit_Error_Count	0x00
Slot_Configuration_CRC_Error_Count	0x01
Reed_Solomon_Error_Count	0x02
ATM_Packet_Loss_Count	0x03

Error Parameter Value

Error_Parameter_Value is a 16-bit unsigned integer representing error counts detected by the NIU.

Number of Connections

Number_of_Connections is an 8-bit unsigned integer that indicates the number of connections that are specified in the response. Specifically, if the number of connections is too large to have a MAC message with less than 40 bytes, it is possible to send separate messages with only the number of connections indicated in each message.

Connection ID

Connection_ID is a 32-bit unsigned integer representing the global connection Identifier used by the NIU for this connection.

Power Control Setting

Power_Control_Setting is an 8-bit unsigned integer representing the absolute power attenuation that the NIU is using for upstream transmission.

Time Offset Value

Time_Offset_Value is a 16-bit short integer representing a relative offset of the upstream transmission timing. A negative value indicates an adjustment forward in time. A positive value indicates an adjustment back in time. The unit of measure is 100 ns.

Upstream Frequency

Upstream_Frequency is a 32-bit unsigned integer representing the IF frequency assigned to the connection. The unit of measure is in Hz.

Downstream Frequency

Downstream_Frequency is a 32-bit unsigned integer representing the IF frequency where the connection resides. The unit of measure is in Hz.

ANNEX B

Radio transmission systems for fixed broadband wireless access (BWA) based on cable modem standards

(based on ITU-T Recommendation J.112, Annex B)

B.0 Scope

This annex "Radio Transmission Systems for Fixed Broadband Wireless Access (BWA) Based on Cable Modem Standards" is based on the standards approved and published by ITU-T for cable modems (specifically Annex B/J.112 "Data over Cable Radio Frequency Interface"), but adapts the technical parameters for use in the wireless access environment, that is for BWA CPE modems. The commonality is maximised to achieve economies of scale.

B.0.1 Conventions

Throughout this annex, the words that are used to define the significance of particular requirements are capitalised. These words are:

"MUST"	This word or the adjective "REQUIRED" means that the item is an absolute requirement of this specification.
"MUST NOT"	This phrase means that the item is an absolute prohibition of this specification.
"SHOULD"	This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
"MAY"	This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

Other text is descriptive or explanatory.

B.0.2 Considerations

ITU-T has developed Recommendations for cable modems, which can be used as the basis for wireless access systems in order to achieve economies of scale. In particular, Annex B/J.112 "Transmission systems for interactive cable television services" and ITU-T J.83 "Digital multiprogramme systems for television, sound and data services for cable distribution" are applicable. The technical parameters for a cable environment can be adapted to the wireless environment in order to support bidirectional data.

The following requirements should be used with radio transmission systems for fixed broadband wireless access based on the cable modem standards of Annex B/J.112.

B.1 General system requirements

B.1.1 Service goals

The intended service will allow transparent bidirectional transfer of ATM and/or Internet Protocol (IP) traffic, between the BWA BTS and customer locations, over a BWA network. This is shown in simplified form in Figure B.1-1.

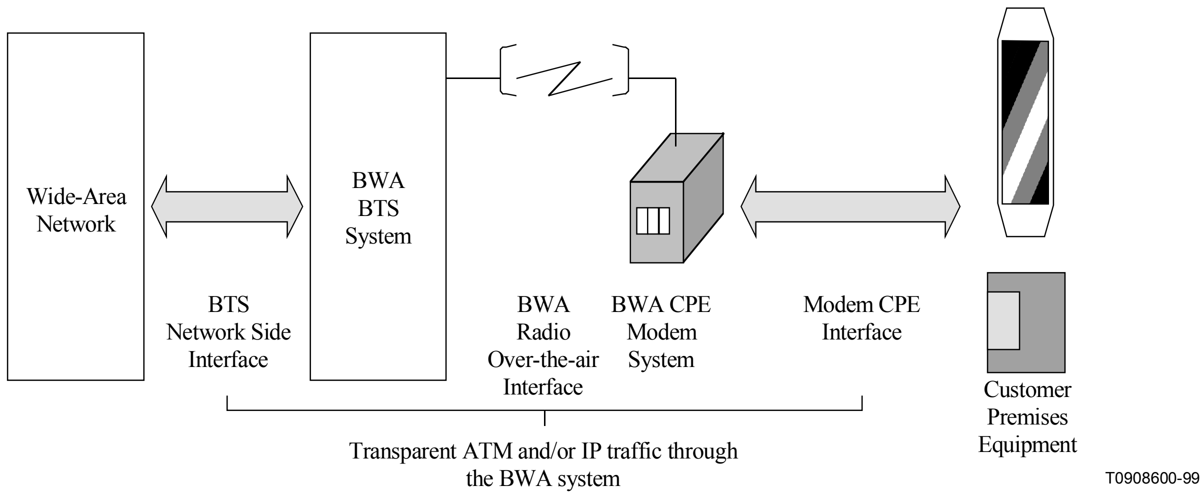


Figure B.1-1/J.116 – Transparent ATM and/or IP traffic through the BWA system

The transmission path over the BWA system is realised at the fixed network side by a BWA Base Transceiver Station (BTS), and at each customer location by a BWA CPE modem. At the fixed network side, the interface to the BWA BTS system is called the BWA Base Transceiver Station – Network-Side Interface (BTS-NSI) and is specified in MCNS3[1]. At the customer locations, the interface is called the CPE-modem-to-customer-premises-equipment interface (CMCI) and is specified in MCNS4[1]. The intent is for the BWA operators to transparently transfer ATM and IP traffic between these interfaces, including but not limited to datagrams, DHCP, ICMP, and IP Group addressing (broadcast and multicast).

B.1.2 Reference architecture

The reference architecture for the data-over-BWA services and interfaces is shown in Figure B.1-2.

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[1] See clause 2.

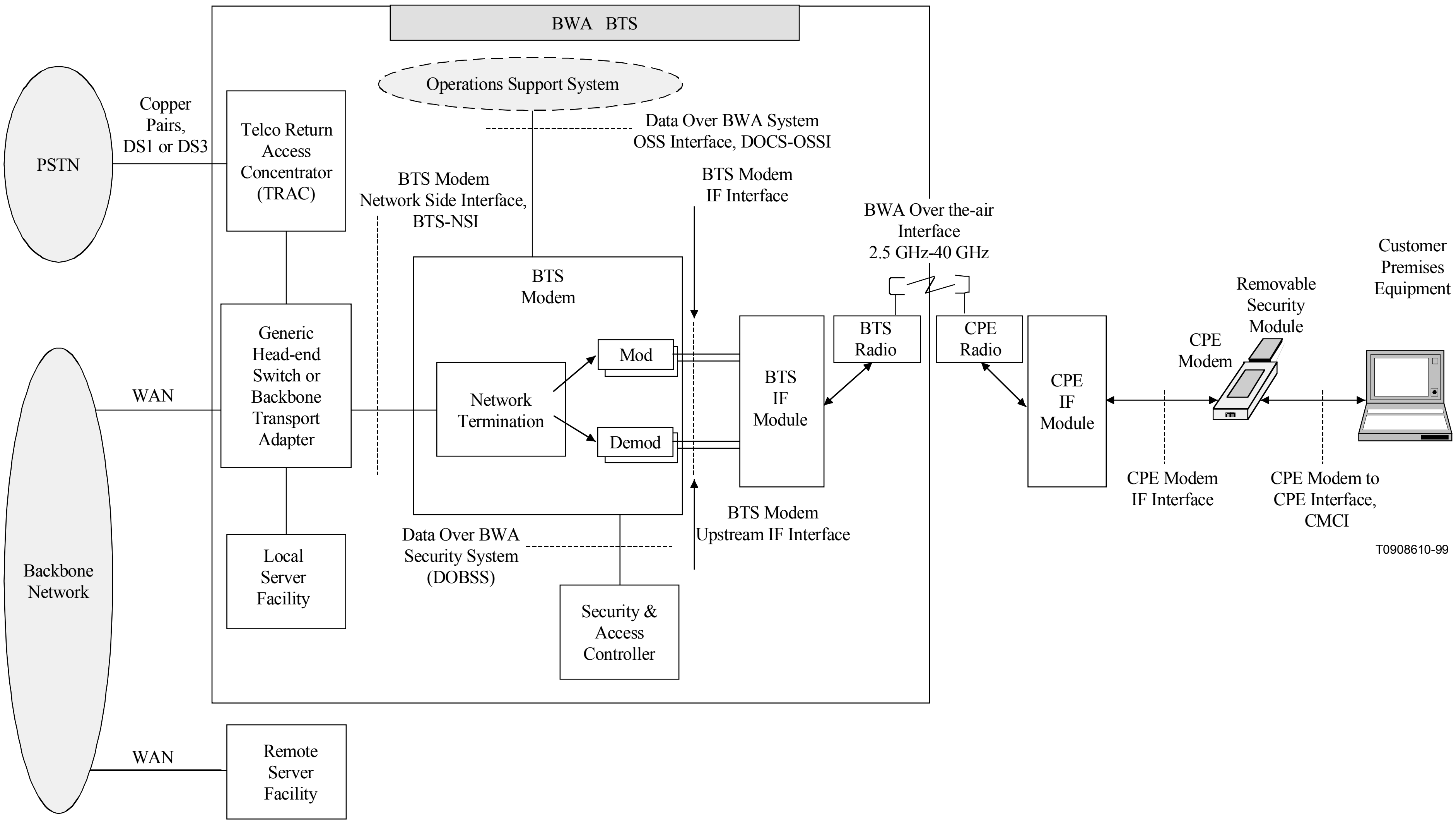

Figure B.1-2/J.116 – Data-over-BWA reference architecture

B.1.3 Categories of interface specification

The basic reference architecture of Figure B.1-2 involves four categories of interface. These are being developed in phases.

a) *Phase 1*

Data Interfaces – These are the CMCI (MCNS4[1]) and BTS-NSI (MCNS3[1]), corresponding respectively to the CPE-modem-to-customer-premises-equipment (CPE) interface (for example, between the customer's computer and the BWA CPE modem), and the BWA BTS modem system network-side interface between the BWA BTS modem and the data network.

b) *Phase 2*

Operations Support Systems Interfaces – These are network element management layer interfaces between the network elements and the high-level OSSs (operations support systems) which support the basic business processes, and are documented in MCNS5[1].

c) *Phase 3*

IF Interfaces – The IF interfaces defined in this annex are the following:

- between the BWA CPE modem and the CPE IF Module;
- between the BTS modem and the BTS IF Module.

d) *Phase 4*

Over the Air Interface – The RF interfaces are defined as follows and Appendix I gives informative details. Recommendations covering the Over the Air Interface are under study by the ITU-R Sector.

- between the BTS radio and the CPE radio in the downstream direction;
- between the BTS radio and the CPE radio in the upstream direction.

Security requirements:

- the Data Over BWA Security System (DOBSS) is defined in MCNS2[1];
- the CPE Removable Security Module (RSM) is defined in MCNS7[1];
- baseline data-over-BWA security is defined in MCNS8[1].

B.1.4 Server location

This annex refers to several servers which are central to the system operation (e.g. provision and security servers).

The message sequence charts used as examples within this annex show sample message exchanges in which access to the servers is via the BTS Modem.

B.2 Functional assumptions

This clause describes the characteristics of a broadband wireless access (BWA) network for the purposes of operation of the data-over-BWA system. The data-over-BWA system MUST operate satisfactorily in the environment described in this clause.

B.2.1 Broadband wireless access (BWA) network

The broadband wireless access (BWA) system uses time division multiple access (TDMA). Information on the key functional characteristics is given in ITU-R F.1499 and Appendix I.

B.2.2 Equipment assumptions

B.2.2.1 Frequency plan

See ITU-R F.1499 and Appendix I.

B.2.2.2 Compatibility with other services

Some of the BWA frequency bands may be shared with satellite applications. In these cases, the mutual interference should be considered and engineered so that both systems will work with minimal performance degradation.

B.2.2.3 Fault isolation impact on other users

As the data-over-BWA system is a shared-media, point-to-multipoint system, fault-isolation procedures MUST take into account the potential harmful impact of faults and fault-isolation procedures on numerous users of the data-over-BWA and other services.

B.2.3 RF channel assumptions

The data-over-BWA system, configured with at least one set of defined physical-layer parameters (e.g. modulation, forward-error correction, symbol rate, etc.) from the range of configuration settings described in this specification, must be capable of operating with a 1500-byte packet loss rate of less than one per cent while forwarding at least 100 packets per second on BWA networks having characteristics defined in clause B.2.3.

B.2.3.1 Transmission upstream and downstream

The RF channel transmission characteristics of the BWA network in both the upstream and downstream directions are described in ITU-R F.1499 and Table I.1.

B.2.3.1.1 Availability

Typical BWA network availability is considerably greater than 99%.

B.2.4 Transmission Levels

Define P_{1dBc} as the 1 dB compression point of the Power Amplifier Output. The precise Output Power value will depend on specific link engineering.

Parameters	Value
BTS Transmit Output Power P_{1dBc}	>15 dBm
CPE Transmit Output Power P_{1dBc}	>15 dBm

B.2.5 Power Control Requirements

No transmit power control is assumed in the downstream direction. Transmit power control is required in the upstream direction.

B.2.6 BER vs. SNR specifications

Due to various symbol rates allowed for the upstream and downstream directions, it is more convenient to specify BER versus SNR. The receive signal level threshold at a particular BER can be decided once the symbol rate and the receiver noise figure are known. The BER vs SNR curves are shown in Figures B.2-1 to B.2-3 for QPSK (4-QAM), 16-QAM and 64-QAM. Raw BER refers to BER without any FEC. BER with RS(204,188) is shown as an example.

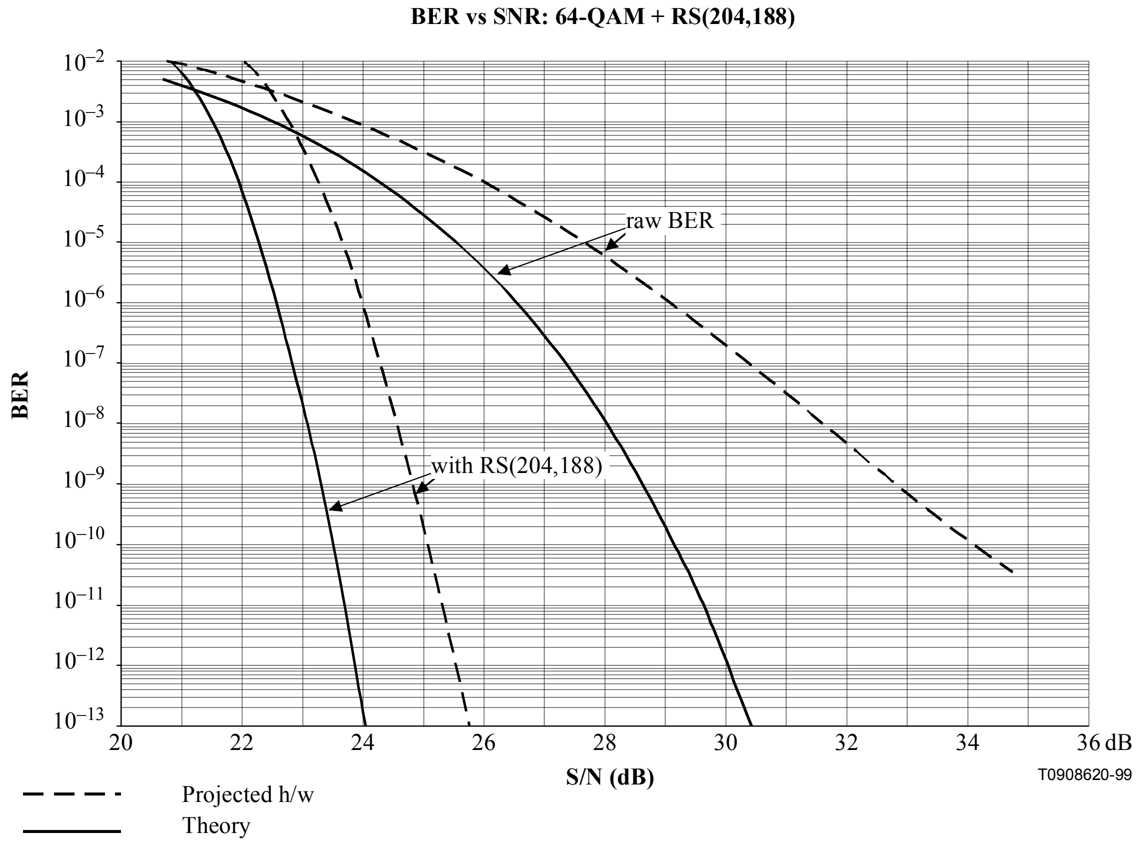

Figure B.2-1/J.116 – BER vs SNR Performance for 64-QAM

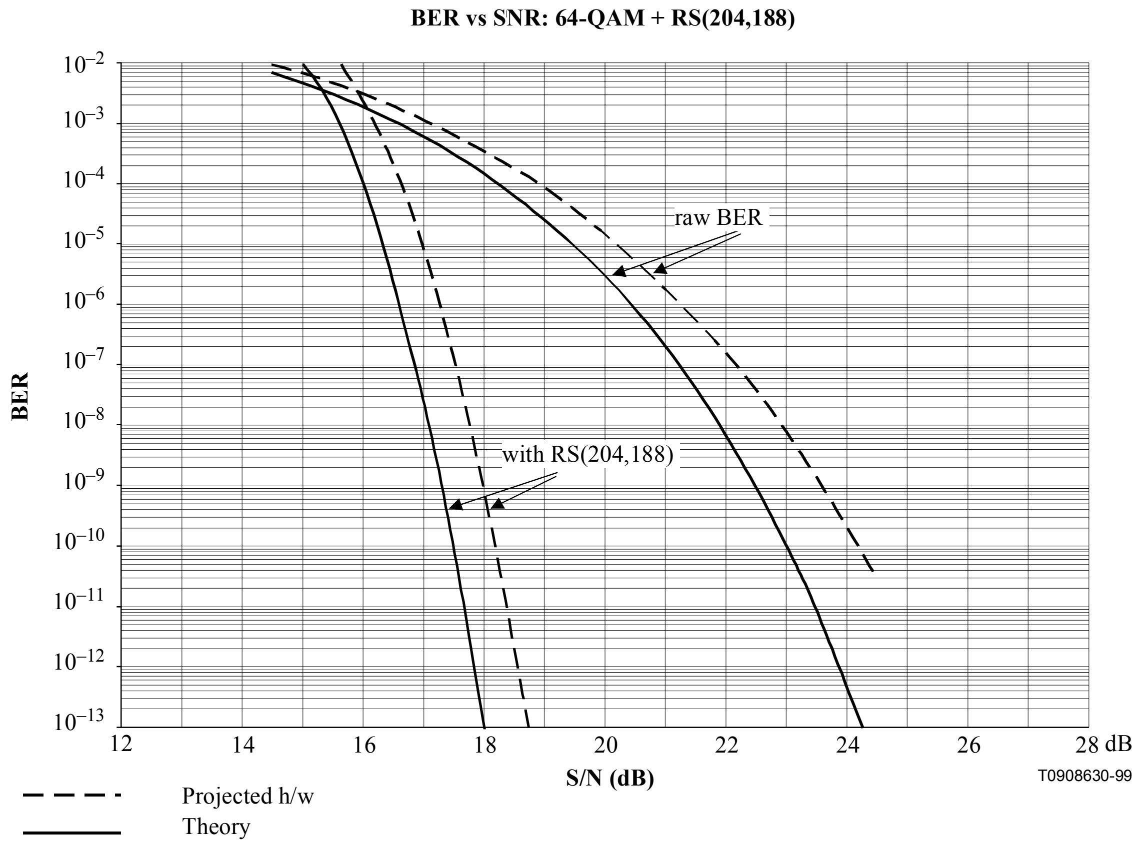

Figure B.2-2/J.116 – BER vs SNR Performance for 16-QAM

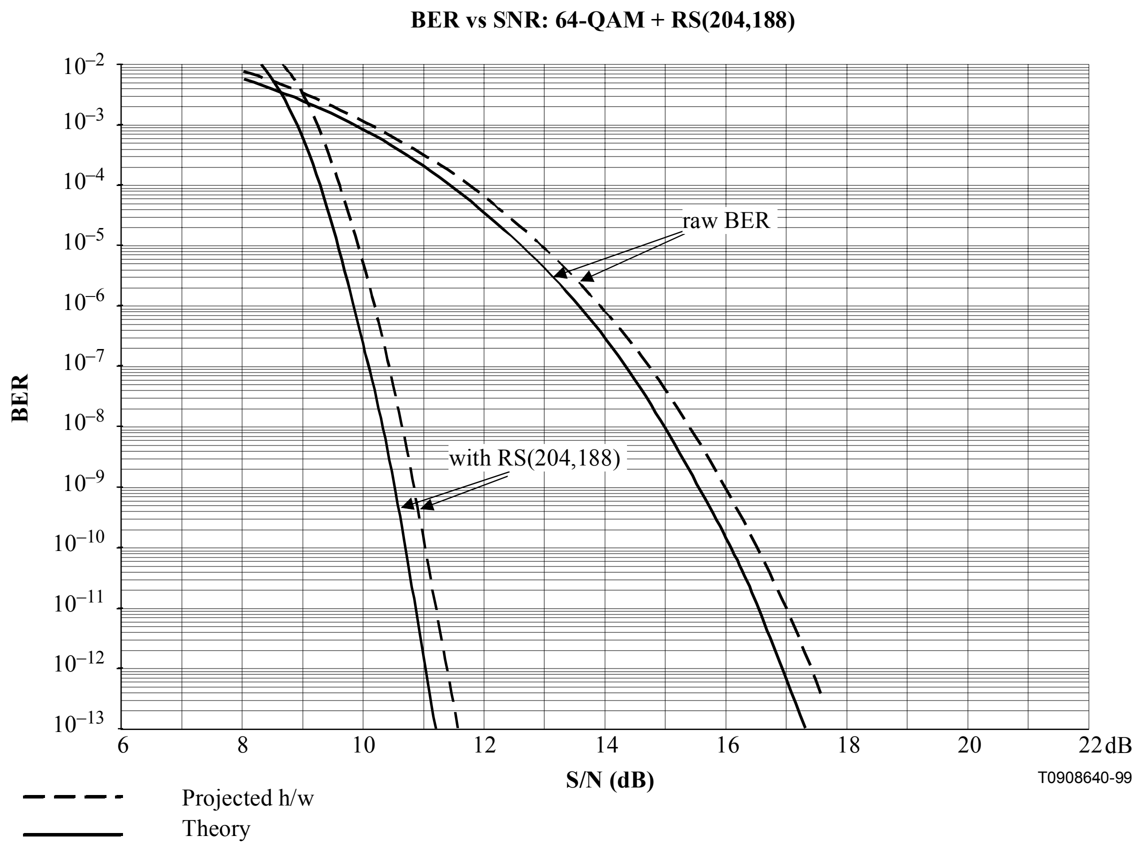

Figure B.2-3/J.116 – BER vs SNR Performance for QPSK (4-QAM)

B.2.7 Frequency inversion

Frequency inversion must be allowed in the transmission path in either the downstream or upstream direction. The modems should have the capability of correcting frequency inversions in the upstream and downstream paths.

B.3 Communication protocols

This clause provides a high-level overview of the communication protocols that MUST be used in the data-over-BWA system. Detailed specifications for the physical media dependent, downstream transmission, and media access control sublayers are provided in B.4, B.5 and B.6 respectively.

B.3.1 Protocol stack

The BWA CPE Modem and BWA BTS Modem operate as forwarding agents and also as end-systems (hosts). The protocol stacks used in these modes differ as shown below.

The principle function of the BWA CPE modem system is to transmit Internet Protocol (IP) packets transparently between the BWA fixed network side and the subscriber location. Certain management functions also ride on IP, so that the protocol stack on the BWA network is as shown in Figure B.3-1 (this does not restrict the generality of IP transparency between the BWA fixed network and the customer). These management functions include, for example, supporting spectrum management functions and the downloading of software.

B.3.1.1 BWA CPE and BWA BTS Modems as Hosts

The BWA CPE and BWA BTS Modems will operate as IP and LLC hosts in terms of IEEE Standard 802 for communication over the BWA network. The protocol stack at the BWA CPE Modem and BWA BTS Modem over-the-air interfaces is shown in Figure B.3-1.

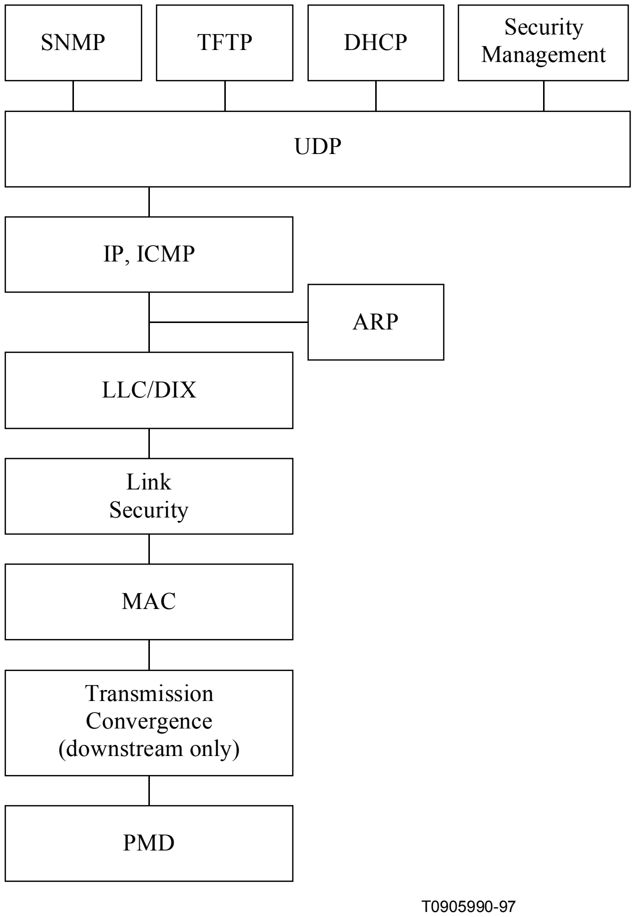

Figure B.3-1/J.116 – Protocol Stack on the over-the-air Interface

The BWA CPE Modem and BWA BTS Modem MUST function as IP hosts. As such, the BWA CPE Modem and BWA BTS Modem MUST support IP and ARP over DIX link-layer framing (see DIX). The BWA CPE Modem and BWA BTS Modem MAY also support IP and ARP over SNAP framing RFC 1042.

The BWA CPE Modem and BWA BTS Modem also MUST function as LLC hosts. As such, the BWA CPE Modem and BWA BTS Modem MUST respond appropriately to TEST and XID requests per ISO/IEC 8802-2.

B.3.1.2 Data forwarding through the BWA CPE and BTS Modems

B.3.1.2.1 General

Data forwarding through the BWA BTS Modem MAY be transparent bridging, or MAY employ network-layer forwarding (routing, IP switching) as shown in Figure B.3-2.

Data forwarding through the BWA CPE Modem is link-layer transparent bridging, as shown in Figure B.3-2. Forwarding rules are similar to ISO/IEC 15802-3 with the modifications described in B.3.1.2.2 and B.3.1.2.3. This allows the support of multiple network layers.

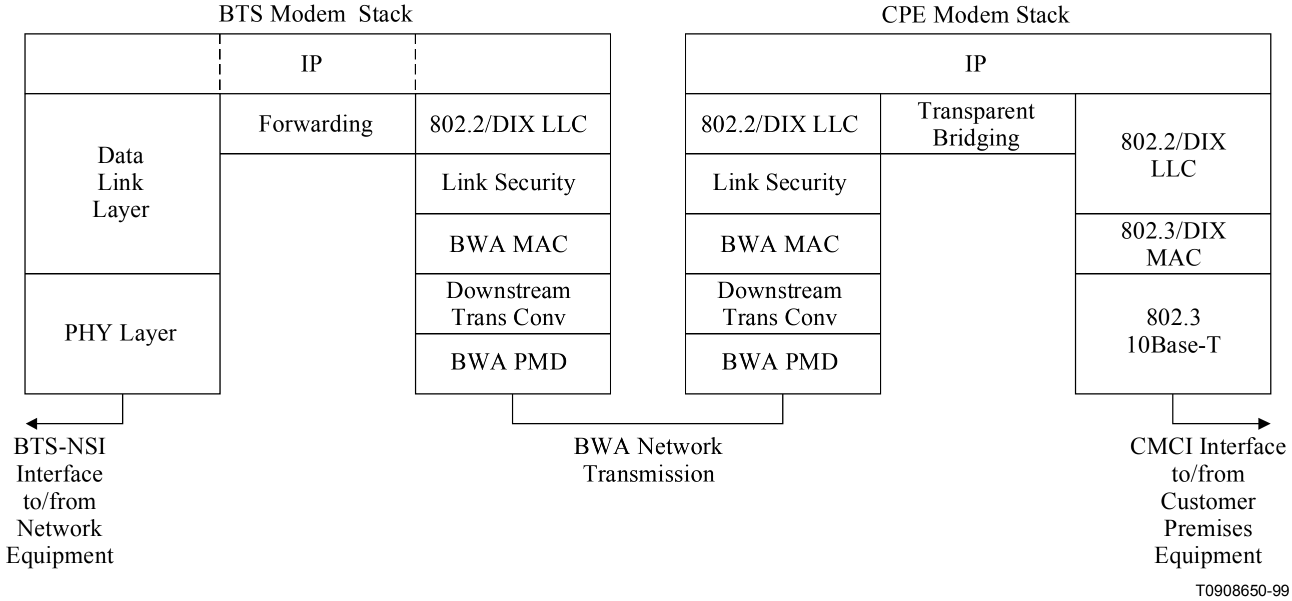

Figure B.3-2/J.116 – Data forwarding through the BWA CPE Modem and the BWA BTS Modem

Forwarding of IP traffic MUST be supported. Support of other network layer protocols is OPTIONAL. The ability to restrict the network layer to a single protocol such as IP is REQUIRED.

Support for the 802.1d spanning tree protocol of ISO/IEC 15802-3 with the modifications described in B.3.1.2.3 is OPTIONAL for CPE Modems intended for residential use. CPE Modems intended for commercial use and bridging BTS Modems MUST support this version of spanning tree. The CPE modem and BTS modem MUST include the ability to filter (and disregard) 802.1d BPDUs.

This specification assumes the CPE modems intended for residential use will not be connected in a configuration which would create network loops such as that shown in Figure B.3-3.

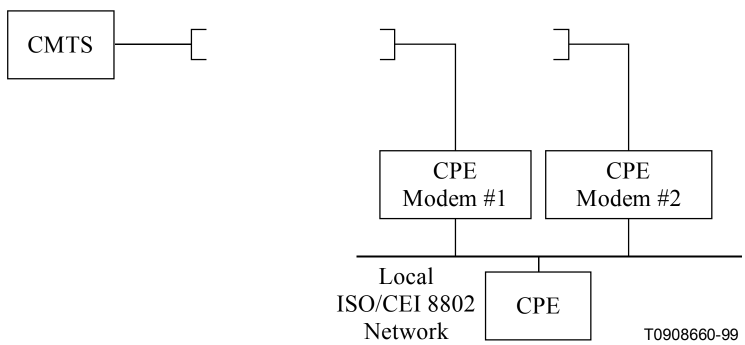

Figure B.3-3/J.116 – Example condition for network loops

B.3.1.2.2 BWA BTS Modem forwarding rules

At the BWA BTS Modem, if link-layer forwarding is used, then it MUST conform to the following general 802.1d guidelines:

- link-layer frames between a given pair of end-stations MUST be delivered in order;
- link-layer frames MUST NOT be duplicated;
- stale frames (those that cannot be delivered in a timely fashion) MUST be discarded.

The address-learning and -ageing mechanisms used are vendor-dependent.

If network-layer forwarding is used, then the BWA BTS Modem should conform to IETF Router Requirements RFC 1812 with respect to its BWA BTS Modem -RFI and BWA BTS Modem -NSI interfaces.

Conceptually, the BWA BTS Modem forwards data packets at two abstract interfaces: between the BWA BTS Modem-RFI and the BWA BTS Modem-NSI, and between the upstream and downstream channels. The BWA BTS Modem MAY use any combination of link-layer (bridging) and network-layer (routing) semantics at each of these interfaces. The methods used at the two interfaces need not be the same.

Forwarding between the upstream and downstream channels within a MAC layer differs from traditional LAN forwarding in that:

- a single channel is simplex, and cannot be considered a complete interface for most protocol (e.g. 802.1d spanning tree, Routing Information Protocol per IETF RFC 1058) purposes;
- upstream channels are essentially point-to-point, whereas downstream channels are shared-media;
- as a public network, policy decisions may override full connectivity.

For these reasons, an abstract entity called the MAC Forwarder exists within the BWA BTS Modem to provide connectivity between stations within a MAC domain (see B.3.2).

B.3.1.2.3 BWA CPE Modem forwarding rules

Data forwarding through the BWA CPE Modem is link-layer bridging with the following specific rules.

B.3.1.2.3.1 Address learning

- The BWA CPE Modem MUST acquire Ethernet MAC addresses of connected CPE devices, either from the provisioning process or from learning, until the BWA CPE Modem acquires its maximum number of CPE addresses (a device-dependent value). Once the BWA CPE Modem acquires its maximum number of CPE addresses, then newly discovered CPE addresses MUST NOT replace previously acquired addresses. The BWA CPE Modem must support acquisition of at least one CPE address.
- The BWA CPE Modem MUST allow configuration of CPE addresses during the provisioning process (up to its maximum number of CPE addresses) to support configurations in which learning is not practical nor desired.
- Addresses provided during the BWA CPE Modem provisioning MUST take preference over learned addresses.
- CPE addresses MUST NOT be aged out.
- On a BWA CPE Modem reset (e.g. a power cycle), all learned and provisioned addresses MUST be discarded (they are not retained in non-volatile storage, to allow modification of user MAC addresses or movement of the BWA CPE Modem). However, a BWA CPE Modem MAY retain any provisioned addresses over a reset.

B.3.1.2.3.2 Forwarding

BWA CPE Modem forwarding in both directions MUST conform to the following general 802.1d guidelines:

- link-layer frames between a given pair of end-stations MUST be delivered in order;
- link-layer frames MUST NOT be duplicated;
- stale frames (those that cannot be delivered in a timely fashion) MUST be discarded.

BWA-Network-to-Ethernet forwarding MUST follow the following specific rules:

- frames addressed to unknown destinations MUST NOT be forwarded from the BWA port to the Ethernet port;
- broadcast frames MUST be forwarded to the Ethernet port;
- multicast frames MUST be forwarded to the Ethernet ports in accordance with filtering configuration settings specified by the BWA system operator's operations and business support systems.

Ethernet-to-BWA Network forwarding MUST follow the following specific rules:

- frames addressed to unknown destinations MUST be forwarded from the Ethernet port to the CPE modem port;
- broadcast frames MUST be forwarded to the CPE Modem port;
- multicast frames MUST be forwarded to the CPE Modem port in accordance with filtering configuration settings specified by the BWA system operator's operations and business support systems;
- frames from source addresses other than those provisioned or learned as supported CPE devices MUST NOT be forwarded;
- if a single-user BWA CPE Modem has learned a supported address, it MUST NOT forward data from a second source. Other (non-supported) CPE source addresses MUST be learned from the Ethernet port and this information used to filter local traffic as in a traditional learning bridge;
- if a single-user BWA CPE Modem has learned A as its supported CPE device and learned B as a second device connected to the Ethernet port, it MUST filter any traffic from A to B.

B.3.2 The MAC Forwarder

The MAC Forwarder is a MAC sublayer that resides on the BWA BTS Modem just below the MAC service access point (MSAP) interface, as shown in Figure B.3-4. It is responsible for delivering upstream frames to:

- one or more downstream channels;
- the MSAP interfaces;

In Figure B.3-4, the LLC sublayer and link security sublayers of the upstream and downstream channels on the BWA network terminate at the MAC Forwarder.

The MSAP interface user MAY be the NSI-RFI Forwarding process of the BWA BTS Modem's host protocol stack.

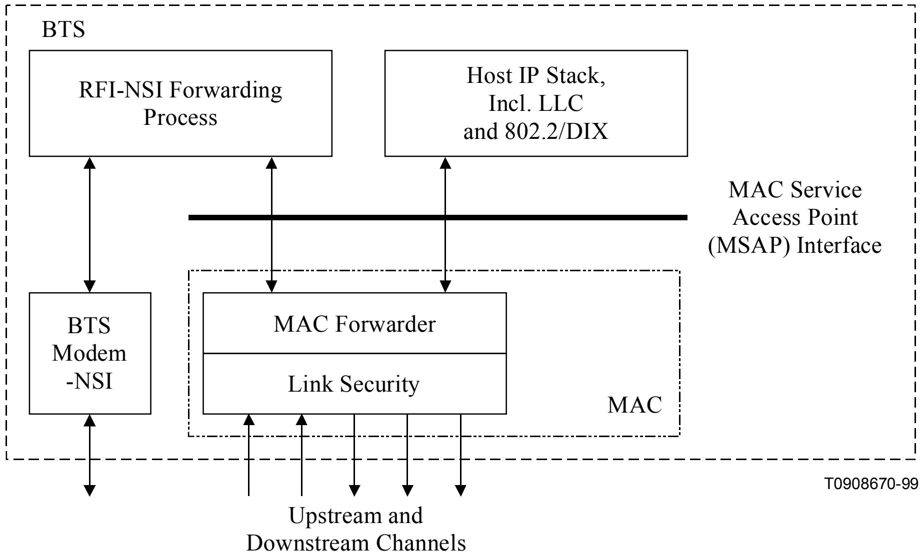

Figure B.3-4/J.116 – MAC Forwarder

Delivery of frames may be based on data-link layer (bridging) semantics, network-layer (routing) semantics, or some combination. Higher-layer semantics may also be employed (e.g. filters on UDP port numbers). The BWA BTS Modem MUST provide IP connectivity between hosts attached to BWA CPE modems, and must do so in a way that meets the expectations of Ethernet-attached customer equipment. For example, the BWA BTS Modem must either forward ARP packets or it must facilitate a proxy ARP service. The BWA BTS Modem MAC Forwarder MAY provide service for non-IP protocols.

Note that there is no requirement that all upstream and downstream channels be aggregated under one MSAP as shown above. The vendor could just as well choose to implement multiple MSAPs, each with a single upstream and downstream channel.

B.3.2.1 Example rules for Data-Link-Layer Forwarding

If the MAC Forwarder is implemented using only data-link semantics, then the requirements in this clause apply.

Delivery of frames is dependent on the Destination Address within the frame. The means of learning the location of each address is vendor-dependent, and MAY include:

- transparent-bridging-like-source-address learning and ageing;
- gleaning from MAC Registration Request messages;
- administrative means.

If the destination address of a frame is unicast, and that address is associated with a particular downstream channel, then the frame MUST be forwarded to that channel.[2]

If the destination address of a frame is unicast, and that address is known to reside on the other (upper) side of the MSAP interface, then the frame MUST be delivered to the MSAP interface.

[2] Vendors may implement extensions, similar to static addresses in IEEE 802.1d/ISO/IEC 10038 bridging, that cause such frames to be filtered or handled in some other manner.

If the destination address is broadcast, multicast[3], or unknown, the frame MUST BE delivered to both the MSAP and to all downstream channels.

Delivery rules are similar to those for transparent bridging:

- frames from a specific source to a particular destination MUST be delivered in order;
- frames MUST NOT be duplicated;
- frames that cannot be delivered in a timely fashion MUST be discarded;
- the Frame Check Sequence SHOULD be preserved rather than regenerated.

B.3.3 Network Layer

As stated above, the purpose of the data-over-BWA system is to transport IP traffic transparently through the system.

The Network Layer protocol is the Internet Protocol (IP) version 4, as defined in IETF RFC 791, and migrating to IP version 6.

This annex imposes no requirements for reassembly of IP packets.

B.3.4 Above the Network Layer

The subscribers will be able to use the transparent IP capability as a bearer for higher-layer services. Use of these services will be transparent to the CPE Modem.

In addition to the transport of user data, there are several network management and operation capabilities which depend upon the Network Layer. These include:

- SNMP (Simple Network Management Protocol, IETF RFC 1157), for network management;
- TFTP (Trivial File Transfer Protocol, IETF RFC 1350), a file transfer protocol, for downloading software and configuration information;
- DHCP (Dynamic Host Configuration Protocol, DHCP IETF RFC 1541), a framework for passing configuration information to hosts on a TCP/IP network;
- a security management protocol as defined in MCNS2[1].

B.3.5 Data Link Layer

The Data Link Layer is divided into sublayers in accordance with IEEE 802, with the addition of Link-Layer security in accordance with MCNS2[1]. The sublayers, from the top, are:

- Logical Link Control (LLC) sublayer (Class 1 only);
- Link-Layer Security sublayer;
- Media Access Control (MAC) sublayer.

B.3.5.1 LLC Sublayer

The LLC Sublayer MUST be provided in accordance with ISO/IEC 15802-1. Address resolution MUST be used as defined in IETF RFC 826. The MAC-to-LLC service definition is specified in ISO/IEC 15802-1.

B.3.5.2 Link-Layer Security Sublayer

Link-Layer security MUST be provided in accordance with MCNS2[1] and MCNS8[1].

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[3] The all-BTS multicast address (see clause 2) is an exception. IEEE 802.1d/ISO/IEC 10038 Spanning Tree Bridge PDUs must be forwarded.

B.3.5.3 MAC Sublayer

The definition, in detail, of the MAC sublayer and associated interfaces is provided in B.6.

The MAC sublayer defines a single transmitter for each downstream channel – the BWA BTS Modem. All BWA CPE Modems listen to all frames transmitted on the downstream channel upon which they are registered and accept those where the destinations match the BWA CPE Modem itself or CPEs reached via the BWA modem to CPE Interface port. BWA CPE Modems can communicate with other BWA CPE Modems only through the BWA BTS Modem.

The upstream channel is characterised by many transmitters (BWA CPE Modems) and one receiver (the BWA BTS Modem). Time in the upstream channel is slotted, providing for Time Division Multiple Access at regulated time ticks. The BWA BTS Modem provides the time reference and controls the allowed usage for each interval. Intervals may be granted for transmissions by particular BWA CPE Modems, or for contention by all BWA CPE Modems. BWA CPE Modems may contend to request transmission time. To a limited extent, BWA CPE Modems may also contend to transmit actual data. In both cases, collisions can occur and retries are used.

Clause B.6 describes the MAC-sublayer messages from the BWA BTS Modem which direct the behaviour of the s on the upstream channel, as well as messaging from the BWA CPE Modem to the BWA BTS Modem.

B.3.5.3.1 Overview

Some of the MAC protocol highlights include:

- bandwidth allocation controlled by BWA BTS Modem;
- a stream of mini-slots in the upstream;
- dynamic mix of contention- and reservation-based upstream transmit opportunities;
- bandwidth efficiency through support of variable-length packets;
- extensions provided for future support of ATM or other Data PDU;
- class-of-service support;
- extensions provided for security as well as Virtual LANs at the Data Link Layer;
- support for a wide range of data rates.

B.3.5.3.2 MAC service definition

The MAC sublayer service definition is detailed in B.13.

B.3.6 Physical Layer

The Physical (PHY) layer is comprised of two sublayers:

- Transmission Convergence sublayer (present in the downstream direction only);
- Physical Media Dependent (PMD) sublayer.

B.3.6.1 Downstream Transmission Convergence Sublayer

The Downstream Transmission Convergence sublayer exists in the downstream direction only. It provides an opportunity for additional services over the physical-layer bitstream. These additional services might include, for example, digital video. Definition of any such additional services is beyond the scope of this Recommendation.

This sublayer is defined as a continuous series of 188-byte MPEG ITU-T H.222.0 packets, each consisting of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the data-over-BWA MAC. Other values of the header may indicate other payloads. The mixture of payloads is arbitrary and controlled by the BWA BTS Modem.

The Downstream Transmission Convergence sublayer is defined in B.5.

B.3.6.2 PMD sublayer

B.3.6.2.1 Overview

The PMD sublayer involves digitally modulated RF carriers over-the-air.

In the downstream direction, the PMD sublayer is based on ITU-T J.83, with the exceptions called out in B.4.3, and includes these features:

- QPSK, 16- and 64-QAM modulation formats;
- up to 40 MHz occupied spectrum;
- Reed-Solomon block code and Trellis code defined per ITU-T J.83;
- variable-depth interleaver supports both latency-sensitive and -insensitive data defined per ITU-T J.83.

The features in the upstream direction are as follows:

- flexible and programmable BWA CPE Modem under control of the BWA BTS Modem;
- frequency agility;
- time division multiple access;
- QPSK and 16-QAM modulation formats;
- support of both fixed-frame and variable-length PDU formats;
- multiple symbol rates;
- programmable Reed-Solomon block coding;
- programmable preambles.

B.3.6.2.2 Interface Points

Three RF interface points are defined at the PMD sublayer:

a) "Downstream output" on the BWA BTS Modem;

b) "Upstream input" on the BWA BTS Modem;

c) "CPE Modem in/out" at the BWA CPE modem.

Separate downstream output and upstream input interfaces on the BWA BTS Modem are required for compatibility with typical downstream and upstream signal combining and splitting arrangements in BWA system.

B.4 Physical Media Dependent Sublayer Specification

B.4.1 Scope

This specification defines the electrical characteristics and protocol for a BWA CPE modem and BWA BTS modem. It is the intent of this specification to define an interoperable BWA CPE Modem and BWA BTS Modem such that any implementation of a BWA CPE Modem can work with any BWA BTS Modem. It is not the intent of this specification to imply any specific implementation.

B.4.2 Upstream

B.4.2.1 Overview

The upstream Physical Media Dependent (PMD) sublayer uses a FDMA/TDMA burst modulation format, which provides variable symbol rates and two modulation formats (QPSK and 16-QAM). The modulation format includes pulse shaping for spectral efficiency, is carrier-frequency agile, and has selectable output power level. The PMD sublayer format includes a variable-length modulated burst with precise timing beginning at boundaries spaced at integer multiples of 6.25 μs apart.

Each burst supports a flexible modulation, symbol rate, preamble, randomisation of the payload, and programmable FEC encoding.

All of the upstream transmission parameters associated with burst transmission outputs from the BWA CPE Modem are configurable by the BWA BTS Modem via MAC messaging. Many of the parameters are programmable on a burst-by-burst basis.

The PMD sublayer can support a near-continuous mode of transmission, wherein ramp-down of one burst MAY overlap the ramp-up of the following burst, so that the transmitted envelope is never zero. The system timing of the TDMA transmissions from the various BWA CPE Modem MUST provide that the centre of the last symbol of one burst and the centre of the first symbol of the preamble of an immediately following burst are separated by at least the duration of several symbols. The guard time MUST be greater than or equal to the duration of five symbols plus the maximum timing error. Timing error is contributed by both the BWA CPE Modem and BWA BTS Modem. BWA CPE Modem timing performance is specified in B.4. Maximum timing error and guard time may vary with BWA BTS Modem from different vendors.

The upstream modulator is part of the BWA CPE modem which interfaces with the BWA network. The modulator contains the actual electrical-level modulation function and the digital signal-processing function; the latter provides the FEC, preamble prepend, symbol mapping, and other processing steps. This specification is written with the idea of buffering the bursts in the signal processing portion, and with the signal processing portion:

1) accepting the information stream a burst at a time;
2) processing this stream into a complete burst of symbols for the modulator; and
3) feeding the properly-timed bursted symbol stream to a memoryless modulator at the exact burst transmit time.

The memoryless portion of the modulator only performs pulse shaping and quadrature upconversion.

At the Demodulator, similar to the Modulator, there are two basic functional components: the demodulation function and the signal processing function. Unlike the Modulator, the Demodulator resides in the BWA BTS Modem and the specification is written with the concept that there will be one demodulation function (not necessarily an actual physical demodulator) for each carrier frequency in use. The demodulation function would receive all bursts on a given frequency.

NOTE – The unit design approach should be cognisant of the multiple-channel nature of the demodulation and signal processing to be carried out at the head-end, and partition/share functionality appropriately to optimally leverage the multi-channel application. A Demodulator design supporting multiple channels in a Demodulator unit may be appropriate.

The demodulation function of the Demodulator accepts a varying-level signal centred around a commanded power level and performs symbol timing and carrier recovery and tracking, burst acquisition and demodulation. Additionally, the demodulation function provides an estimate of burst timing relative to a reference edge, an estimate of received signal power, an estimate of signal-to-noise ratio, and may engage adaptive equalisation to mitigate the effects of multipath and IF circuit distortion. The signal-processing function of the Demodulator performs the inverse processing of the signal-processing function of the Modulator. This includes accepting the demodulated burst data stream and decoding, etc., and possibly multiplexing the data from multiple channels into a single output stream. The signal-processing function also provides the edge-timing reference and gating-enable signal to the demodulators to activate the burst acquisition for each assigned burst slot. The signal-processing function may also provide an indication of successful decoding, decoding error, or fail-to-decode for each codeword and the number of corrected Reed-Solomon symbols in each codeword.

B.4.2.2 Modulation formats

The upstream modulator MUST provide both QPSK and optionally 16-QAM and/or 64-QAM modulation formats.

The upstream demodulator MUST support QPSK, and optionally 16-QAM and/or 64-QAM.

B.4.2.2.1 Modulation rates

The upstream modulator MUST provide QPSK and the symbol rate must be selected from the following list: 160, 320, 640, 1280, 2560, 5120, 10 240, and 20 480 ksym/s. The upstream modulator optional should provide 16-QAM and/or 64-QAM and the symbol rate must be selected from the following list: 160, 320, 640, 1280, 2560, 5120, 10 240, and 20 480 ksym/s.

The upstream symbol rate MUST be fixed for each upstream frequency.

B.4.2.2.2 Symbol Mapping

The modulation mode (QPSK or 16-QAM or 64-QAM) should be programmable. The symbols transmitted in each mode and the mapping of the input bits to the I and Q constellation MUST be as defined in Table B.4-1. In this table, I1 is the MSB of the symbol map, Q1 is the LSB for QPSK, and Q0 is the LSB for 16-QAM. Q1 and I0 have intermediate bit positions in 16-QAM. The MSB MUST be the first bit in the serial data into the symbol mapper.

Table B.4-1/J.116 – I/Q Mapping

QAM Mode	Input bit Definitions
QPSK	I1 Q1
16-QAM	I1 Q1 I0 Q0

The upstream QPSK symbol mapping MUST be as shown in Figure B.4-1.

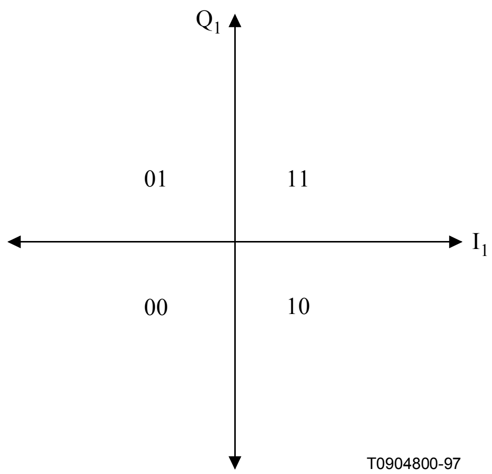


Figure B.4-1/J.116 – QPSK symbol mapping

The 16-QAM non-inverted (Gray-coded) symbol mapping MUST be as shown in Figure B.4-2.

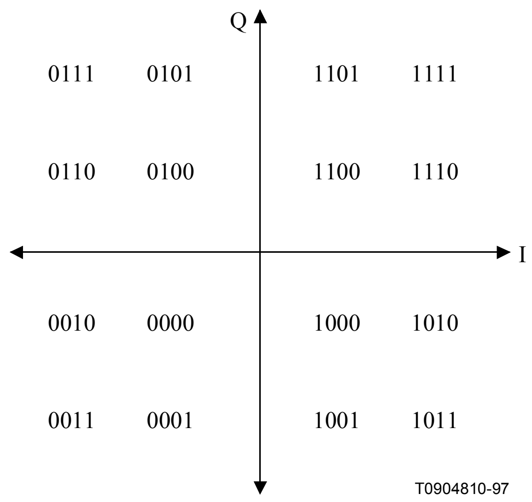


Figure B.4-2/J.116 – 16-QAM Gray-Coded Symbol Mapping

The 16-QAM differential symbol mapping MUST be as shown in Figure B.4-3.

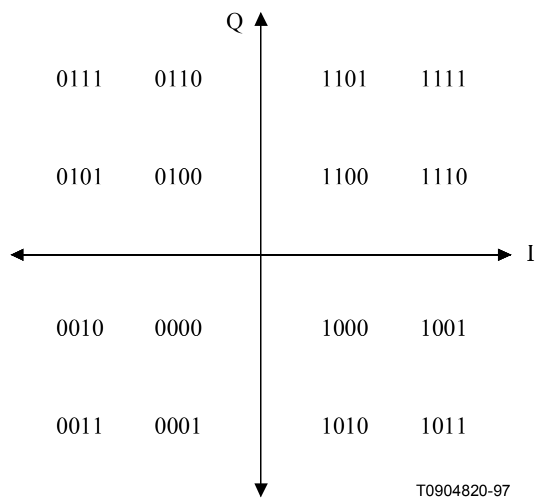


Figure B.4-3/J.116 – 16-QAM Differential-Coded Symbol Mapping

If differential quadrant encoding is enabled, then the currently-transmitted symbol quadrant is derived from the previously transmitted symbol quadrant and the current input bits via Table B.4-2.

Table B.4-2/J.116 – Derivation of currently transmitted symbol quadrant

Current input bits I(1) Q(1)	Quadrant phase change	MSBs of previously transmitted symbol	MSBs for currently transmitted symbol
00	0º	11	11
00	0º	01	01
00	0º	00	00
00	0º	10	10
01	90º	11	01
01	90º	01	00
01	90º	00	10
01	90º	10	11
11	180º	11	00
11	180º	01	10
11	180º	00	11
11	180º	10	01
10	270º	11	10
10	270º	01	11
10	270º	00	01
10	270º	10	00

B.4.2.2.3 Spectral shaping

The upstream PMD sublayer MUST support a 25% Nyquist square root raised cosine shaping.

The occupied spectrum MUST NOT exceed the channel widths shown in Table B.4-3.

Table B.4-3/J.116 – Maximum channel width

Symbol rate (ksym/s)	Channel Width (kHz) (Note)
160	200
320	400
640	800
1280	1600
2560	3200
5120	6400
10 240	13 000
20 480	26 000
NOTE – Channel width is the –30 dB bandwidth.	

B.4.2.2.4 Upstream Frequency Agility and Range

For Upstream frequency range, see ITU-R F.1499 and Appendix I.

B.4.2.2.5 Spectrum format

The upstream modulator MUST provide operation with the format s(t) = I(t)*cos(ωt) ± Q(t)*sin(ωt), where t denotes time and ω denotes angular frequency.

B.4.2.3 FEC encode

The upstream modulator MUST be able to provide the following selections: Reed-Solomon codes over GF(256) with T = 1 to 10 or no FEC coding.

The Reed-Solomon generator polynomial MUST be supported:

$$g(x) = \left(x + \alpha^0\right)\left(x + \alpha^1\right)\left(x + \alpha^{2T-1}\right)$$

The Reed-Solomon generator polynomial MUST be supported:

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1$$

The upstream modulator MUST provide codewords from 3 to 255 bytes in size. The uncoded word size can have a minimum of one byte.

In Shortened Last Codeword mode, the BWA CPE Modem MUST provide the last codeword of a burst shortened from the assigned length of k data bytes per codeword as described in B.4.2.10.1.2.

The value of T MUST be configured in response to the Upstream Channel Descriptor from the BWA BTS Modem.

B.4.2.4 Scrambler (Randomiser)

The upstream modulator MUST implement a scrambler (shown in Figure B.4-4) where the 15-bit seed value MUST be arbitrarily programmable.

At the beginning of each burst, the register is cleared and the seed value is loaded. The seed value MUST be used to calculate the scrambler bit which is combined in an XOR with the first bit of data of each burst (which is the MSB of the first symbol following the last symbol of the preamble).

The scrambler seed value MUST be configured in response to the Upstream Channel Descriptor from the BWA BTS modem.

The polynomial MUST be $x^{15} + x^{14} + 1$.

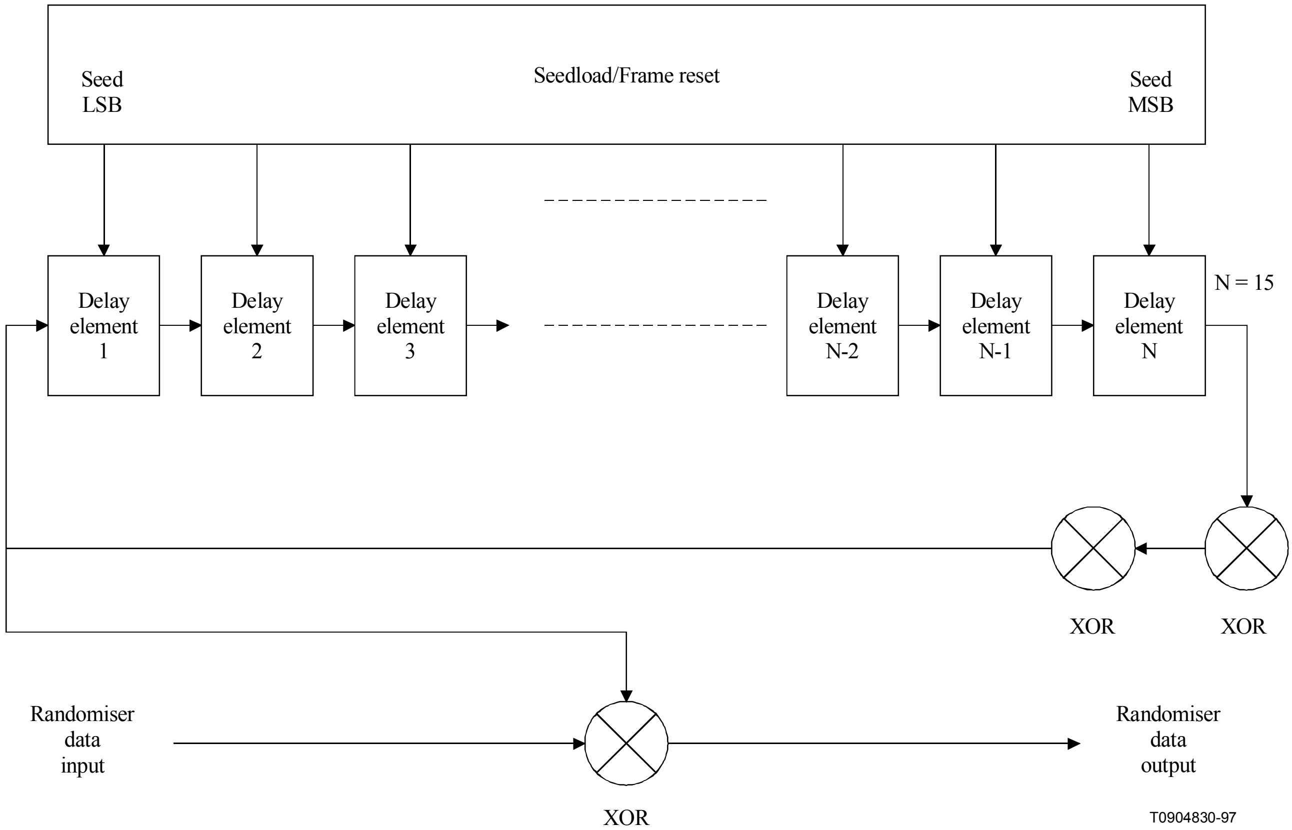


Figure B.4-4/J.116 – Scrambler structure

B.4.2.5 Preamble prepend

The upstream PMD sublayer MUST support a variable-length preamble field that is prepended to the data after they have been randomised and Reed-Solomon encoded.

The value of the preamble that is prepended MUST be programmable and the length MUST be 0, 2, 4, ... , or 1024 bits for QPSK and 0, 4, 8, ... , or 1024 bits for 16-QAM. Thus, the maximum length of the preamble is 512 QPSK symbols or 256-QAM symbols.

The preamble length and value MUST be configured in response to the Upstream Channel Descriptor message transmitted by the BWA BTS Modem.

B.4.2.6 Burst profiles

The burst profiles are separated into two portions:

a) Channel Burst Parameters, which are common to all users assigned to a given channel using that burst type; and

b) User Unique Parameters, which vary for each user even when using the same burst type on the same channel as another user (for example, Power Level).

In addition to these parameters, the assigned centre frequencies and mini-slot grants MUST also be provided by the BWA BTS Modem.

The upstream PMD sublayer MUST support a minimum of four distinct burst profiles to be stored within the BWA CPE Modem, with variable parameters as defined in Table B.4-4. User Unique parameters are defined in Table B.4-5.

Table B.4-4/J.116 – Channel burst parameters

Parameter	Configuration settings
Modulation	QPSK, 16-QAM
Diff Enc	On/Off
Symbol Rate	8 configuration settings
Preamble Length	0-1024 bits (see B.4.2.5)
Preamble Values	1024 bits
FEC On/Off	On/Off
FEC Codeword Information Bytes (k)	Fixed: 1 to 253 (assuming FEC on) Shortened: 16 to 253 (assuming FEC on)
FEC Error Correction (T bytes)	0 to 10
Scrambler Seed	15 bits
Burst Length m mini-slots (Note)	0 to 255
Last Codeword Length	Fixed, shortened
Guard Time	5 to 255 symbols
NOTE – A burst length of 0 mini-slots in the Channel Profile means that the burst length is variable on that channel for that burst type. The burst length, while not fixed, is granted explicitly by the BWA BTS Modem to the BWA CPE Modem in the MAP.	

Table B.4-5/J.116 – User unique burst parameters

Parameter	Configuration settings
Transmit Power Level (Note) (minimum range) (at antenna flange)	See ITU-R F.1499 and Appendix I
Offset Frequency (Note)	Range = ±350 kHz
Spectrum Inversion	Normal, Inverted
Ranging Offset	0 to (2^{16} – 1), increments of 6.25 µs/64
Burst Length (mini-slots) if variable on this channel (changes burst-to-burst)	1 to 255 mini-slots
Transmit Equaliser Coefficients (Note) (advanced modems only)	Up to 64 coefficients; 4 bytes per coefficient: 2 real and 2 complex
NOTE – Values in table apply for this given channel and symbol rate.	

Ranging Offset is the delay correction applied by the BWA CPE Modem to the BWA BTS Modem Upstream Frame Time derived at the BWA CPE modem, in order to synchronise the upstream transmissions in the TDMA scheme. The Ranging Offset is an advancement equal to roughly the round-trip delay of the BWA CPE Modem from the BWA BTS modem. The BWA BTS Modem MUST provide feedback correction for this offset to the BWA CPE modem, based on reception of one or more successfully received bursts (i.e. satisfactory result from each technique employed: error correction and/or CRC), with accuracy within 1/2 symbol and resolution of 1/64 of the frame tick increment (6.25 µs/64 = 0.09765625 µs).

The BWA BTS Modem sends adjustments to the BWA CPE Modem, where a negative value implies the Ranging Offset is to be decreased, resulting in later times of transmission at the BWA CPE Modem. The BWA CPE Modem MUST implement the correction with resolution of at most 1 symbol duration (of the symbol rate in use for a given burst), and (other than a fixed bias) with accuracy within ±0.25 ms plus ±1/2 symbol owing to resolution. The accuracy of BWA CPE Modem burst timing of ±0.25 ms plus ±1/2 symbol is relative to the mini-slot boundaries derivable at the BWA CPE Modem based on an ideal processing of the timestamp signals received from the BWA BTS Modem.

The BWA CPE Modem MUST be capable of switching burst profiles with no reconfiguration time required between bursts except for changes in the following parameters:

1) Output Power;
2) Modulation;
3) Symbol Rate;
4) Offset frequency;
5) Channel Frequency; and
6) Ranging Offset.

For Modulation, Symbol Rate, Offset frequency and Ranging Offset, the BWA CPE Modem MUST be able to transmit consecutive bursts as long as the BWA BTS Modem allocates at least 25 symbols in between the last symbol centre of one burst and the first symbol centre of the following burst. The BWA CPE Modem MUST implement, and have settled, changes in Output Power, Modulation, Symbol Rate, or Offset frequency 12.5 symbols or more before the symbol centre of the first symbol of a transmitted burst and 12.5 symbols or more after the symbol centre of the last symbol of a transmitted burst. Output Power, Modulation, Symbol Rate, Offset frequency, Channel Frequency and Ranging Offset MUST NOT be changed until the BWA CPE Modem is provided sufficient time between bursts by the BWA BTS Modem.

If Channel Frequency is to be changed, then the BWA CPE Modem MUST be able to implement the change between bursts as long as the BWA BTS Modem allocates at least 25 symbols plus 100 ms between the last symbol centre of one burst and the first symbol centre of the following burst.

The Channel Frequency of the BWA CPE Modem MUST be settled within the phase noise and accuracy requirements of B.4.2.9.5 and B.4.2.9.6 within 100 ms from the beginning of the change.

If Output Power is to be changed by 1 dB or less, then the BWA CPE Modem MUST be able to implement the change between bursts as long as the BWA BTS Modem allocates at least 25 symbols plus 5 µs between the last symbol centre of one burst and the first symbol centre of the following burst.

If Output Power is to be changed by more than 1 dB, then the BWA CPE Modem MUST be able to implement the change between bursts as long as the BWA BTS Modem allocates at least 25 symbols plus 10 µs between the last symbol centre of one burst and the first symbol centre of the following burst.

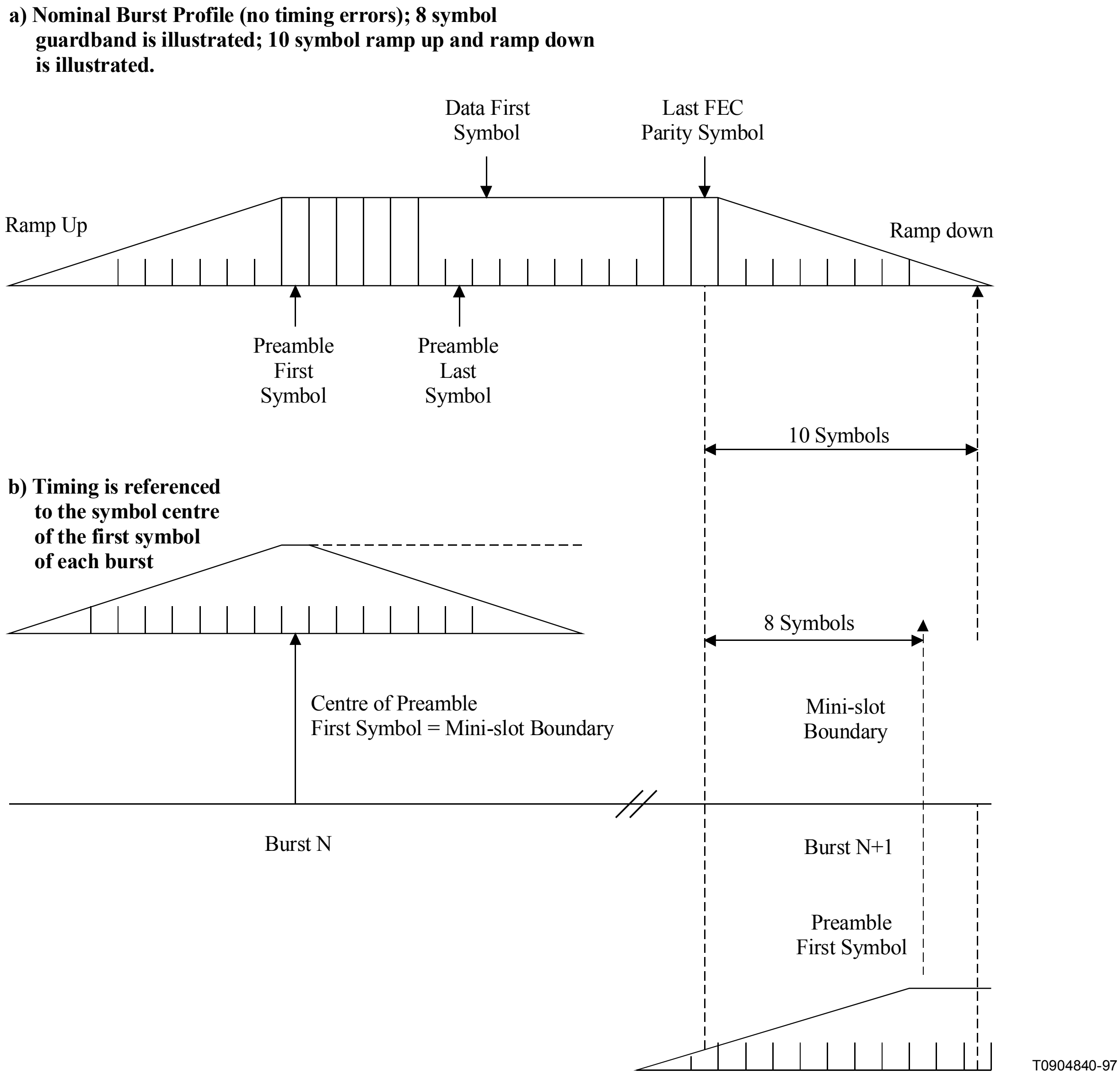
The Output Power of the BWA CPE Modem MUST be settled to within 0.1 dB of its final output power level:

a) within 5 µs from the beginning of a change of 1 dB or less; and
b) within 10 µs from the beginning of a change of greater than 1 dB.

The output transmit power MUST be maintained constant within a TDMA burst to within less than 0.1 dB (excluding the amount theoretically present due to pulse shaping, and amplitude modulation in the case of 16-QAM).

B.4.2.7 Burst timing convention

Figure B.4-5 illustrates the nominal burst timing.



NOTE – Ramp down of one burst can overlap ramp up of following burst even with one transmitter assigned both bursts.

Figure B.4-5/J.116 – Nominal burst timing

Figure B.4-6 indicates worst-case burst timing. In this example, burst N arrives 1.5 symbols late, and burst N+1 arrives 1.5 symbols early, but separation of 5 symbols is maintained; 8-symbol guardband shown.

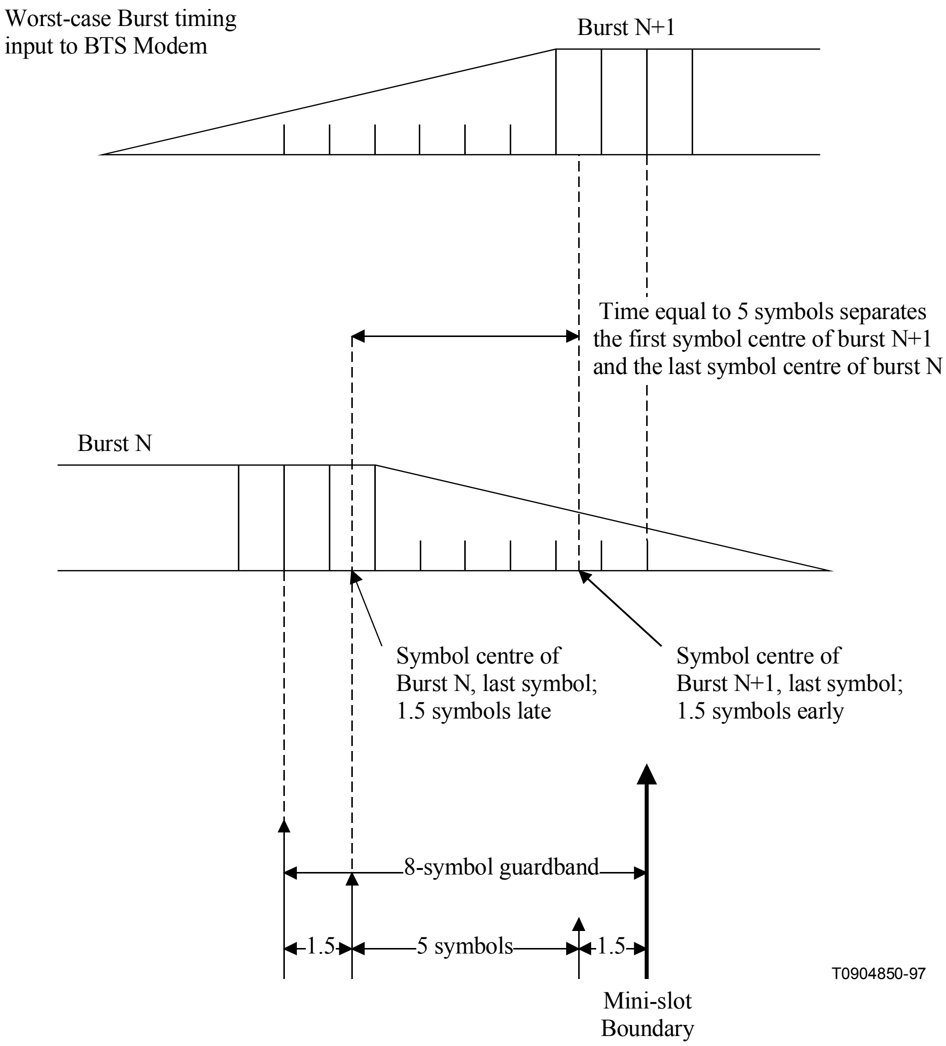


Figure B.4-6/J.116 – Worst-case burst timing

At a symbol rate of Rs, symbols occur at a rate of one each Ts = 1/Rs seconds. Ramp Up and Ramp Down are the spread of a symbol in the time domain beyond Ts duration owing to the symbol-shaping filter. If only one symbol were transmitted, its duration would be longer than Ts due to the shaping filter impulse response being longer than Ts. The spread of the first and last symbols of a burst transmission effectively extends the duration of the burst to longer than N * Ts, where N is the number of symbols in the burst.

B.4.2.8 Transmit power requirements

The upstream PMD sublayer MUST support varying the amount of transmit power. Requirements are presented for:

1) the range of commanded transmit power;
2) the step size of the power commands; and
3) the accuracy (actual output power compared to the commanded amount) of the response to the command.

The mechanism by which power adjustments are performed is defined in B.7.2.4. Such adjustments MUST be within the ranges of tolerances described below.

B.4.2.8.1 Output Power Agility and Range

The output transmit power in the design bandwidth MUST be variable over the minimum range of –27 dBm to +17 dBm (16-QAM), –30 dBm to +20 dBm (QPSK), in 1 dB steps.

The absolute accuracy of the transmitted power MUST be ±2 dB, and step size accuracy ±0.4 dB. For example, the actual power increase resulting from a command to increase the power level by 1 dB in a BWA CPE modems next transmitted burst MUST be between 0.6 dB and 1.4 dB.

B.4.2.9 Fidelity requirements

B.4.2.9.1 Spurious emissions

The noise and spurious power MUST NOT exceed the levels given in Table B.4-6 for reliable operation. The measurement bandwidth is equal to the symbol rate (e.g. 160 kHz for 160 ksym/s) for the requirements. In any case, the spurious emissions MUST meet local national and regional limits.

Table B.4-6/J.116 – Spurious Emissions

Parameter	Transmitting burst	Between bursts
In-band	–40 dBc	The greater of –72 dBc or –97 dBm
Adjacent Band	–45 dBc	The greater of –72 dBc or –97 dBm

B.4.2.9.2 Spurious emissions during burst on/off transients

Each transmitter MUST control spurious emissions, prior to and during ramp up and during and following ramp down, before and after a burst in the TDMA scheme.

On/off spurious emissions, such as the change in voltage at the upstream transmitter output due to enabling or disabling transmission, MUST be no more than 100 mV, and such a step MUST be dissipated no faster than 2 μs of constant slewing. This requirement applies when the BWA CPE is transmitting at +20 dBm or more; at backed-off transmit levels, the maximum change in voltage MUST decrease by a factor of 2 for each 6 dB decrease of power level from +20 dBm, down to a maximum change of 7 mV at –4 dBm and below. This requirement does not apply to BWA CPE Modem power-on and power-off transients.

B.4.2.9.3 Bit Error Rate (BER)

Overall modem performance MUST be within 1.5 dB of theoretical uncoded BER vs C/N, at BER = 10^{-6}, for QPSK and 16-QAM.

B.4.2.9.4 Filter distortion

The following requirements assume that any pre-equalisation is disabled.

B.4.2.9.4.1 Amplitude

The spectral mask MUST be the ideal square root raised cosine spectrum with alpha = 0.25, within the ranges given below:

$f_c - R_s/4$ Hz to $f_c + R_s/4$ Hz: –0.3 dB to +0.3 dB

$f_c - 3R_s/8$ Hz to $f_c - R_s/4$ Hz, and $f_c + R_s/4$ Hz to $f_c + 3R_s/8$ Hz: –0.5 dB to 0.3 dB

$f_c - R_s/2$ Hz and $f_c + R_s/2$ Hz: –3.5 dB to –2.5 dB

$f_c - 5R_s/8$ Hz and $f_c + 5R_s/8$ Hz: no greater than –30 dB

where f_c is the centre frequency and R_s is the symbol rate.

B.4.2.9.4.2 Phase

$f_c - 5R_s/8$ Hz to $f_c + 5R_s/8$ Hz: Group Delay Variation MUST NOT be greater than 100 ns.

B.4.2.9.5 Carrier phase noise

The upstream transmitter total integrated phase noise (including discrete spurious noise) MUST be less than or equal to –43 dBc summed over the spectral regions spanning 1 kHz to 1.6 MHz above and below the carrier.

B.4.2.9.6 Channel frequency accuracy

The BWA CPE MUST implement the assigned channel frequency within ±5 parts per million over a temperature range of –40 to 75º C up to five years from date of manufacture.

B.4.2.9.7 Symbol Rate Accuracy

The upstream modulator MUST provide an absolute accuracy of symbol rates ±50 parts per million over a temperature range of 0 to 40º C up to five years from date of manufacture.

B.4.2.9.8 Symbol timing jitter

Peak-to-peak symbol jitter, referenced to the previous symbol zero-crossing, of the transmitted waveform, MUST be less than 0.02 of the nominal symbol duration over a 2 s period. In other words, the difference between the maximum and the minimum symbol duration during the 2 s period shall be less than 0.02 of the nominal symbol duration for each of the eight upstream symbol rates.

The peak-to-peak cumulative phase error, referenced to the first symbol time and with any fixed symbol frequency offset factored out, MUST be less than 0.04 of the nominal symbol duration over a 0.1 s period. In other words, the difference between the maximum and the minimum cumulative phase error during the 0.1 s period shall be less than 0.04 of the nominal symbol duration for each of the eight upstream symbol rates. Factoring out a fixed symbol frequency offset is to be done by using the computed mean symbol duration during the 0.1 s.

B.4.2.10 Frame structure

Figure B.4-7 shows two examples of the frame structure: one where the packet length equals the number of information bytes in a codeword, and another where the packet length is longer than the number of information bytes in one codeword, but less than in two codewords. Example 1 illustrates the fixed codeword-length mode, and Example 2 illustrates the shortened last codeword mode. These modes are defined in B.4.2.10.1.

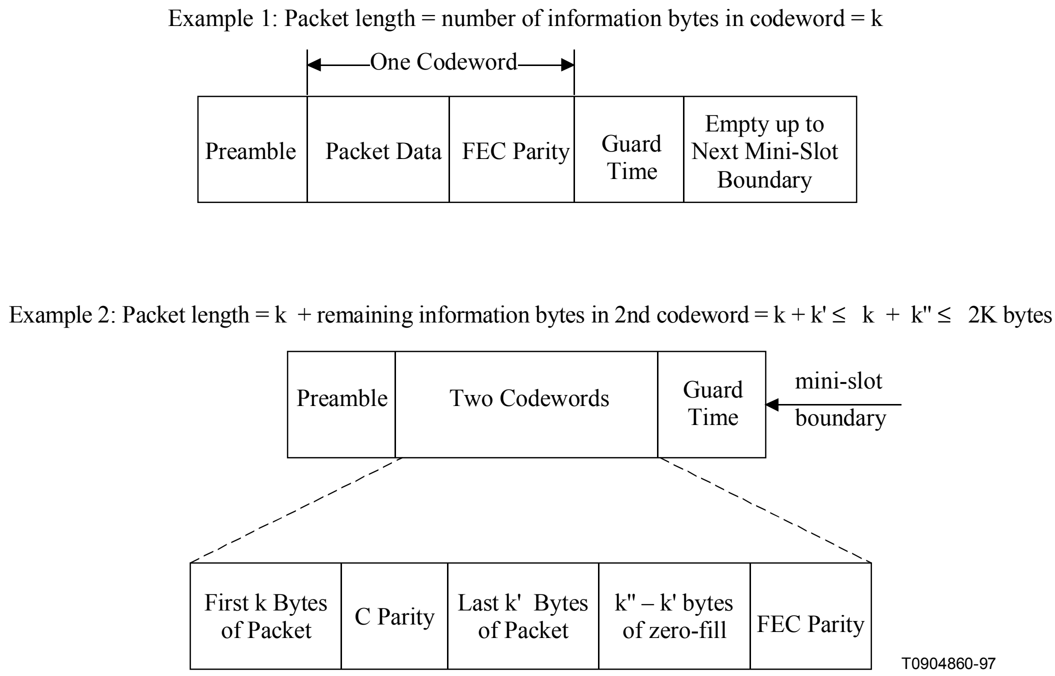


Figure B.4-7/J.116 – Example frame structures with flexible burst length mode

B.4.2.10.1 Codeword length

The BWA CPE Modem operates in fixed-length codeword mode or with shortened codeword capability enabled. Shortened codeword capability is available with $k \geq 16$ bytes, where k is the number of information bytes in a codeword. With $k < 16$, shortened codeword capability is not available.

The following descriptions apply to an allocated grant of mini-slots in both contention and non-contention regions. (Allocation of mini-slots is discussed in B.6.) The intent of the description is to define rules and conventions such that BWA CPE Modems request the proper number of mini-slots and the BWA BTS Modem PHY knows what to expect regarding the FEC framing in both fixed codeword length and shortened last codeword modes.

B.4.2.10.1.1 Fixed codeword length

With the fixed-length codewords, after all the data are encoded, zero-fill will occur in this codeword if necessary to reach the assigned k data bytes per codeword, and zero-fill MUST continue up to the point when no additional fixed-length codewords can be inserted before the end of the last allocated min-slot in the grant, accounting for FEC parity and guard-time symbols.

B.4.2.10.1.2 Shortened last codeword

As shown in Figure B.4-7, let k' = the number of information bytes that remain after partitioning the information bytes of the burst into full-length (k burst data bytes) codewords. The value of k' is less than k. Given operation in a shortened last codeword mode, let k'' = the number of burst data bytes plus zero-fill bytes in the shortened last codeword. In shortened codeword mode, the BWA CPE Modem will encode the data bytes of the burst (including MAC Header) using the assigned codeword size (k information bytes per codeword) until:

1) all the data are encoded; or
2) a remainder of data bytes is left over which is less than k.

Shortened last codewords shall not have less than 16 information bytes, and this is to be considered when BWA CPE Modems make requests of mini-slots. In shortened last codeword mode, the BWA CPE Modem will zero-fill data if necessary until the end of the mini-slot allocation, which in most cases will be the next mini-slot boundary, accounting for FEC parity and guard-time symbols. In many cases, only $k'' - k'$ zero-fill bytes are necessary to fill out a mini-slot allocation with $16 \leq k'' \leq k$ and $k' \leq k''$. However, note the following.

More generally, the BWA CPE Modem is required to zero-fill data until the point when no additional fixed-length codewords can be inserted before the end of the last allocated mini-slot in the grant (accounting for FEC parity and guard-time symbols), and then, if possible, a shortened last codeword of zero-fill shall be inserted to fit into the mini-slot allocation.

If, after zero-fill of additional codewords with k information bytes, there are less than 16 bytes remaining in the allocated grant of mini-slots, accounting for parity and guard-time symbols, then the BWA CPE Modem shall not create this last shortened codeword.

B.4.2.11 Signal processing requirements

The signal processing order for each burst packet type MUST be compatible with the sequence shown in Figure B.4-8 and MUST follow the order of steps in Figure B.4-9.

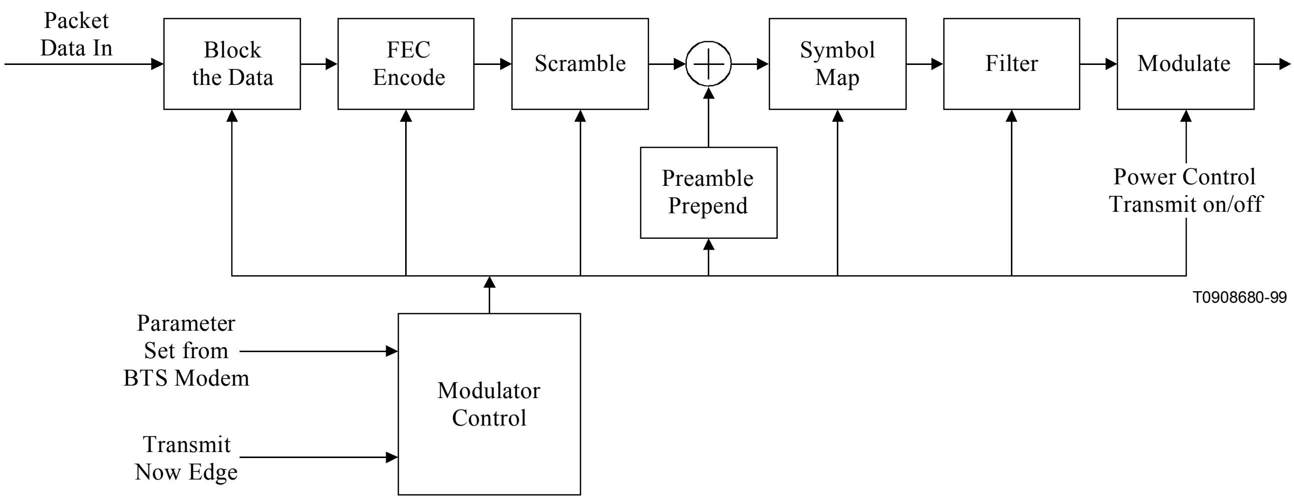


Figure B.4-8/J.116 – Signal processing sequence

	Packet Stream Input
	⇓
Block the Data	Separate Packet into Information Blocks(=data bytes in one codeword)
	⇓
FEC Encode	FEC Encode (Reed-Solomon) each Information Block, using shortened codeword for last block if needed. FEC can be turned off
	⇓
Scramble	Scramble (see paragraph B.4.2.4)
	⇓
Preamble Prepend	Preamble prepend Symbols
	⇓
Symbol Map	Symbol Map the Data Stream into Modulator Symbols
	⇓
Filter	Filter Symbol Stream for Spectral Shaping
	⇓
Modulate	Modulate at Precise Times (QPSK; 16-QAM)
	⇓
	Output RF Waveform Bursts

Figure B.4-9/J.116 – TDMA upstream transmission processing

B.4.2.12 Upstream receiver input power characteristics

All CPEs MUST implement upstream power control so that the various bursts from different CPEs arrive at the BWA BTS with more or less the same power level. The objective receive signal at the BTS receiver depends upon the specific power control algorithm implemented. Once the objective receive signal level is defined, the demodulator MUST operate within its defined performance specifications with received bursts within ±6 dB of the nominal commanded received power.

B.4.2.13 Upstream electrical output from the BWA CPE Modem

The BWA CPE Modem MUST output an RF modulated signal with the characteristics delineated in Table B.4-7.

Table B.4-7/J.116 – Electrical RF Output from BWA CPE

Parameter	Value
Frequency	See ITU-R F.1499 and Appendix I
Minimum Level range (one channel)	See ITU-R F.1499 and Appendix I
Modulation Type	QPSK and optionally 16-QAM and/or 64-QAM
Symbol Rate (nominal)	160, 320, 640, 1280, 2560, 5120, 10 240, and 20 480 ksym/s
Bandwidth	200, 400, 800, 1600, 3200, 6400, 13 000, and 26 000 kHz
Output impedance	50 Ohms
Output Return Loss	>6 dB

B.4.3 Downstream

B.4.3.1 Downstream Protocol

The downstream PMD sublayer MUST conform to ITU-T J.83, with the exceptions of 256-QAM and those called out in B.4.3.2. The downstream PMD sublayer MUST support QPSK, 16-QAM and optionally 64-QAM modulations and symbol rates and bandwidth defined in Table B.4-9.

B.4.3.2 Scalable interleaving to support low latency

The downstream PMD sublayer MUST support a variable-depth interleaver with the characteristics defined in ITU-T J.83, except those with latencies greater than 4 ms.

The interleaver depth, which is coded in a 4-bit control word contained in the FEC frame synchronisation trailer, always reflects the interleaving in the immediately following frame. In addition, errors are allowed while the interleaver memory is flushed after a change in interleaving is indicated.

Refer to ITU-T J.83 for the control bit specifications required to specify which interleaving mode is used.

B.4.3.3 Downstream frequency plan

For Downstream frequency plan, see ITU-R F.1499 and Appendix I. The channel bandwidth is 40 MHz.

B.4.3.4 BWA BTS output electrical

The BWA BTS MUST output an RF modulated signal with the following characteristics defined in Table B.4-8.

Table B.4-8/J.116 – BWA BTS RF Output

Parameter	Value
Centre Frequency (fc)	See ITU-R F.1499 and Appendix I
Transmit Power Level (at tx antenna flange)	See ITU-R F.1499 and Appendix I
Modulation Type	QPSK, 16-QAM and optionally 64-QAM
Symbol Rate (R_S)	Up to 34.78 Msym/s
Nominal Channel Spacing	Up to 40 MHz
Frequency response	12%~18% Square Root Raised Cosine shaping
Spurious and Noise Inband (fc ± R_S/2) Adjacent channel (fc ± R_S/2) to (fc ± 1.25 * R_S/2) Adjacent channel (fc ± 1.25 * R_S/2) to (fc ± 3 * R_S/2) Next adjacent channel (fc ± 3 * R_S/2) to (fc ± 5 * R_S/2)	 < –50 dBc in symbol rate bandwidth (R_S) < –51 dBc in a bandwidth of R_S/8 < –55 dBc, in 1.75 * R_S, excluding up to 3 spurs, each of which must be < –53 dBc when measured in a 10 kHz band < –58 dBc in symbol rate bandwidth (R_S)
Output Impedance	50 Ohms
Output Return Loss	>14 dB

B.4.3.5 Downstream RF input to BWA CPE

The BWA CPE MUST accept an RF modulated signal with the following characteristics (Table B.4-9).

Table B.4-9/J.116 – RF input to BWA CPE

Parameter	Value
Centre Frequency	See ITU-R F.1499 and Appendix I
Level Range (one channel)	–87 dBm to –32 dBm
Modulation Type	QPSK, 16-QAM and optionally 64-QAM
Symbol Rate (nominal)	Up to 34.78 Msym/s
Bandwidth	Up to 40 MHz with 12%~18% Square Root Raised Cosine shaping
Input (load) Impedance	50 Ohms
Input Return Loss	>14 dB

B.4.3.6 BWA CPE Modem BER performance

The bit-error-rate performance of a BWA CPE Modem MUST be as described in this subclause.

B.4.3.6.1 QPSK

B.4.3.6.1.1 QPSK BWA CPE Modem BER performance

Implementation loss of the BWA CPE Modem MUST be such that the BWA CPE Modem achieves a post-FEC BER less than or equal to 10^{-8} when operating at a carrier-to-noise ratio (C/N) of 10.8 dB or greater.

B.4.3.6.1.2 QPSK adjacent channel performance

Performance as described in B.4.3.6.1.1 MUST be met with digital signal at 0 dBc in the adjacent channels.

Performance as described in B.4.3.6.1.1, with an additional 0.2 dB allowance, MUST be met with digital signal at +10 dBc in the adjacent channels.

B.4.3.6.2 16-QAM

B.4.3.6.2.1 16-QAM BWA CPE Modem BER performance

Implementation loss of the BWA CPE Modem MUST be such that the BWA CPE Modem achieves a post-FEC BER less than or equal to 10^{-8} when operating at a carrier-to-noise ratio (C/N) of 17.8 dB or greater.

B.4.3.6.2.2 16-QAM adjacent channel performance

Performance as described in B.4.3.6.2.1 MUST be met with digital signal at 0 dBc in the adjacent channels.

Performance as described in B.4.3.6.2.1, with an additional 0.2 dB allowance, MUST be met with digital signal at +10 dBc in the adjacent channels.

B.4.3.6.3 64-QAM

B.4.3.6.3.1 64-QAM BWA CPE Modem BER performance

Implementation loss of the BWA CPE Modem MUST be such that the BWA CPE Modem achieves a post-FEC BER less than or equal to 10^{-8} when operating at a carrier-to-noise ratio (C/N) of 24.5 dB or greater.

B.4.3.6.3.2 64-QAM adjacent channel performance

Performance as described in B.4.3.6.3.1 MUST be met with digital signal at 0 dBc in the adjacent channels.

Performance as described in B.4.3.6.3.1, with an additional 0.2 dB allowance, MUST be met with digital signal at +10 dBc in the adjacent channels.

B.5 Downstream transmission convergence sublayer

B.5.1 Introduction

In order to improve demodulation robustness, facilitate common receiving hardware for both video and data, and provide an opportunity for the possible future multiplexing of video and data over the PMD sublayer bitstream defined in B.4, a sublayer is interposed between the downstream PMD sublayer and the Data-Over-BWA MAC sublayer.

The downstream bitstream is defined as a continuous series of 188-byte MPEG H.222.0 packets. These packets consist of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the Data-Over-BWA MAC. Other values of the header may indicate other payloads. The mixture of MAC payloads and those of other services is optional and is controlled by the BWA BTS Modem.

Figure B.5-1 illustrates the interleaving of Data-Over-BWA (DOC) MAC bytes with other digital information (digital video in the example shown).

header = DOC	DOC MAC payload
header = video	digital video payload
header = video	digital video payload
header = DOC	DOC MAC payload
header = video	digital video payload
header = DOC	DOC MAC payload
header = video	digital video payload
header = video	digital video payload
header = video	digital video payload

Figure B.5-1/J.116 – Example of interleaving MPEG packets in downstream

B.5.2 MPEG Packet format

The format of an MPEG Packet carrying BWA data is shown in Figure B.5-2. The packet consists of a 4-byte MPEG Header, a pointer_field (not present in all packets) and the BWA Payload.

MPEG Header (4 bytes)	pointer_field (1 byte)	BWA Payload (183 or 184 bytes)

Figure B.5-2/J.116 – Format of an MPEG Packet

B.5.3 MPEG header for BWA data-over-the-air

The format of the MPEG Transport Stream header is defined in 2.4/H.222.0. The particular field values that distinguish Data-Over-BWA MAC streams are defined in Table B.5-1. Field names are from ITU-T H.222.0.

The MPEG Header consists of 4 bytes that begin the 188-byte MPEG Packet. The format of the header for use on an BWA Data-Over-BWA PID is restricted to that shown in Table B.5-1. The header format conforms to the MPEG standard, but its use is restricted in this specification to NOT ALLOW inclusion of an adaptation_field in the MPEG packets.

Table B.5-1/J.116 – MPEG header format for BWA data-over-BWA packets

Field	Length (bits)	Description
sync_byte	8	0x47; MPEG Packet Sync byte
transport_error_indicator	1	Indicates an error has occurred in the reception of the packet. This bit is reset to zero by the sender, and set to one whenever an error occurs in transmission of the packet
payload_unit_start_indicator	1	A value of one indicates the presence of a pointer_field as the first byte of the payload (fifth byte of the packet)
transport_priority	1	Reserved; set to zero
PID (Note)	13	Data-Over-BWA well-known PID (0x1FFE)
transport_scrambling_control	2	Reserved, set to "00"
adaptation_field_control	2	"01"; use of the adaptation_field is NOT ALLOWED on the BWA PID
continuity_counter	4	cyclic counter within this PID
NOTE – In the future, additional PIDs MAY be assigned to a BWA CPE Modem. See B.9.3.		

B.5.4 MPEG payload for BWA data-over-the-air

The MPEG payload portion of the MPEG packet will carry the BWA MAC frames. The first byte of the MPEG payload will be a "pointer_field" if the payload_unit_start_indicator (PUSI) of the MPEG header is set.

stuff_byte

This Recommendation defines a stuff_byte pattern having a value (0xFF) that is used within the BWA payload to fill any gaps between the BWA MAC frames. This value is chosen as an unused value for the first byte of the BWA MAC frame. The "FC" byte of the MAC Header will be defined to never contain this value. (FC_TYPE = "11" indicates a MAC-specific frame, and FC_PARM = "11111" is not currently used and, according to this specification, is defined as an illegal value for FC_PARM.)

pointer_field

The pointer_field is present as the fifth byte of the MPEG packet (first byte following the MPEG header) whenever the PUSI is set to one in the MPEG header. The interpretation of the pointer_field is as follows:

The pointer_field contains the number of bytes in this packet that immediately follow the pointer_field that the BWA CPE Modem decoder must skip past before looking for the beginning of an BWA MAC Frame. A pointer field MUST be present if it is possible to begin an BWA Frame in the packet, and MUST point to the beginning of the first MAC frame to start in the packet or to any preceding stuff_byte.

B.5.5 Interaction with the MAC sublayer

MAC frames may begin anywhere within an MPEG packet, MAC frames may span MPEG packets, and several MAC frames may exist within an MPEG packet.

The following figures show the format of the MPEG packets that carry BWA MAC frames. In all cases, the PUSI flag indicates the presence of the pointer_field as the first byte of the MPEG payload.

Figure B.5-3 shows a MAC frame that is positioned immediately after the pointer_field byte. In this case, pointer_field is zero, and the BWA decoder will begin searching for a valid FC byte at the byte immediately following the pointer_field.

MPEG Header (PUSI = 1)	pointer_field (= 0)	MAC Frame (up to 183 bytes)	stuff_byte(s) (0 or more)

Figure B.5-3/J.116 – Packet format where a MAC frame immediately follows the pointer_field

Figure B.5-4 shows the more general case where a MAC Frame is preceded by the tail of a previous MAC Frame and a sequence of stuffing bytes. In this case, the pointer_field still identifies the first byte after the tail of Frame #1 (a stuff_byte) as the position where the decoder should begin searching for a legal MAC sublayer FC value. This format allows the multiplexing operation in the BWA BTS Modem to immediately insert a MAC frame that is available for transmission if that frame arrives after the MPEG header and pointer_field have been transmitted.

In order to facilitate multiplexing of the MPEG packet stream carrying BWA data with other MPEG-encoded data, the BWA BTS Modem SHOULD NOT transmit MPEG packets with the BWA PID which contain only stuff_bytes in the payload area. MPEG null packets SHOULD be transmitted instead. Note that there are timing relationships implicit in the BWA MAC sublayer which must also be preserved by any MPEG multiplexing operation.

MPEG Header (PUSI = 1)	pointer_field (= M)	Tail of MAC Frame #1 (M bytes)	stuff-byte(s) (0 or more)	Start of MAC Frame #2

Figure B.5-4/J.116 – Packet format with MAC frame preceded by stuffing bytes

Figure B.5-5 shows that multiple MAC frames may be contained within the MPEG packet. The MAC frames may be concatenated one after the other or be separated by an optional sequence of stuffing bytes.

MPEG Header (PUSI = 1)	pointer_field (= 0)	MAC Frame #1	MAC Frame #2	stuff_byte(s) (0 or more)	MAC Frame #3

Figure B.5-5/J.116 – Packet format showing multiple MAC frames in a single packet

Figure B.5-6 shows the case where a MAC frame spans multiple MPEG packets. In this case, the pointer_field of the succeeding frame points to the byte following the last byte of the tail of the first frame.

MPEG Header (PUSI = 1)	pointer_field (= 0)	stuff_bytes (0 or more)	Start of MAC Frame #1 (up to 183 bytes)	
MPEG Header (PUSI = 0)	Continuation of MAC Frame #1 (184 bytes)			
MPEG Header (PUSI = 1)	pointer_field (= M)	Tail of MAC Frame #1 (M bytes)	stuff-byte(s) (0 or more)	Start of MAC Frame #2 (M bytes)

Figure B.5-6/J.116 – Packet format where a MAC frame spans multiple packets

The Transmission Convergence sublayer must operate closely with the MAC sublayer in providing an accurate timestamp to be inserted into the Time Synchronisation message (refer to B.6.3.2.1 and B.6.5).

B.5.6 Interaction with the physical layer

The MPEG-2 packet stream MUST be encoded according to ITU-T J.83, including MPEG-2 transport framing using a parity checksum as described in ITU-T J.83.

B.5.7 MPEG header synchronisation and recovery

The MPEG-2 packet stream SHOULD be declared "in frame" (i.e. correct packet alignment has been achieved) when five consecutive correct parity checksums, each 188 bytes from the previous one, have been received.

The MPEG-2 packet stream SHOULD be declared "out of frame", and a search for correct packet alignment started, when nine consecutive incorrect parity checksums are received.

The format of MAC frames is described in detail in B.6.

B.6 Media access control specification

B.6.1 Introduction

B.6.1.1 Overview

This clause describes version 1.0 of the BWA MAC protocol. Some of the MAC protocol highlights include:

- Bandwidth allocation controlled by BWA BTS Modem.
- A stream of mini-slots in the upstream.
- Dynamic mix of contention- and reservation-based upstream transmit opportunities.
- Bandwidth efficiency through support of variable-length packets.
- Extensions provided for future support of ATM or other Data PDU.
- Class of service support.
- Extensions provided for security as well as virtual LANs at the Data Link layer.
- Support for a wide range of data rates.

B.6.1.2 Definitions

B.6.1.2.1 MAC-sublayer domain

A MAC-sublayer domain is a collection of upstream and downstream channels for which a single MAC Allocation and Management protocol operates. Its attachments include one BWA BTS Modem and some number of BWA CPE Modems. The BWA BTS Modem MUST service all of the upstream and downstream channels; each BWA CPE Modem MAY access one or more upstream and downstream channels.

B.6.1.2.2 MAC service access point

A MAC Service Access Point (MSAP) is an attachment to a MAC-sublayer domain.

B.6.1.2.3 Service ID

The concept of Service IDs is central to the operation of the MAC protocol. Service IDs provide both device identification and class-of-service management. In particular, they are integral to upstream bandwidth allocation.

A Service ID defines a particular mapping between a BWA CPE Modem and the BWA BTS Modem. This mapping is the basis on which bandwidth is allocated to the BWA CPE Modem by the BWA BTS Modem and by which class of service is implemented. Within a MAC-sublayer domain, all Service IDs MUST be unique.

The BWA BTS Modem MAY assign one or more Service IDs (SIDs) to each BWA CPE Modem, corresponding to the classes of service required by the BWA CPE Modem. This mapping MUST be negotiated between the BWA BTS Modem and the BWA CPE Modem during BWA CPE Modem registration.

In a basic BWA CPE Modem implementation, a single Service ID can be used; for example to offer best-effort IP service. However, the Service ID concept allows for more complex BWA CPE Modems to be developed with support for multiple service classes while supporting interoperability with more basic modems. In particular, the Service ID concept is expected to support the concept of "data flows" on which protocols such as RSVP and RTP are based.

The Service ID is unique within a single MAC-sublayer domain. The length of the Service ID is 14 bits (although the Service ID is sometimes carried in a 16-bit field).

B.6.1.2.4 Upstream intervals, mini-slots and 6.25-microsecond increments

The upstream transmission time-line is divided into intervals by the upstream bandwidth allocation mechanism. Each interval is an integral number of mini-slots. A "mini-slot" is the unit of granularity for upstream transmission opportunities. There is no implication that any PDU can actually be transmitted in a single mini-slot. Each interval is labelled with a usage code which defines both the type of traffic that can be transmitted during that interval and the physical-layer modulation encoding. A mini-slot is an integer multiple of 6.25 μs increments. The relationship between mini-slots, bytes, and time ticks is described further in B.6.5.4. The usage code values are defined in Table B.6-15 and allowed use is defined in B.6.3. The binding of these values to physical-layer parameters is defined in Table B.6-13.

B.6.1.2.5 Frame

A frame is a unit of data exchanged between two (or more) entities at the Data Link Layer. A MAC frame consists of a MAC Header (beginning with a Frame Control byte; see Figure B.4-4), and may incorporate ATM cells or a variable-length data PDU. The variable-length PDU includes a pair of 48-bit addresses, data, and a CRC sum. In special cases, the MAC Header may encapsulate multiple MAC frames (see B.6.2.5.4).

B.6.1.3 Future Use

A number of fields are defined as being "for future use" in the various MAC frames described in this annex. These fields MUST NOT be interpreted or used in any manner by this version (1.0) of the MAC protocol.

B.6.2 MAC frame formats

B.6.2.1 Generic MAC frame format

A MAC frame is the basic unit of transfer between MAC sublayers at the BWA BTS Modem and the BWA CPE modem. The same basic structure is used in both the upstream and downstream directions. MAC frames are variable in length. The term "frame" is used in this context to indicate a unit of information that is passed between MAC sublayer peers. This is not to be confused with the term "framing" that indicates some fixed timing relationship.

There are three distinct regions to consider, as shown in Figure B.6-1. Preceding the MAC frame is either PMD sublayer overhead (upstream) or an MPEG transmission convergence header (downstream). The first part of the MAC frame is the MAC Header. The MAC Header uniquely identifies the contents of the MAC frame. Following the header is the optional Data PDU region. The format of the Data PDU and whether it is even present is described in the MAC Header.

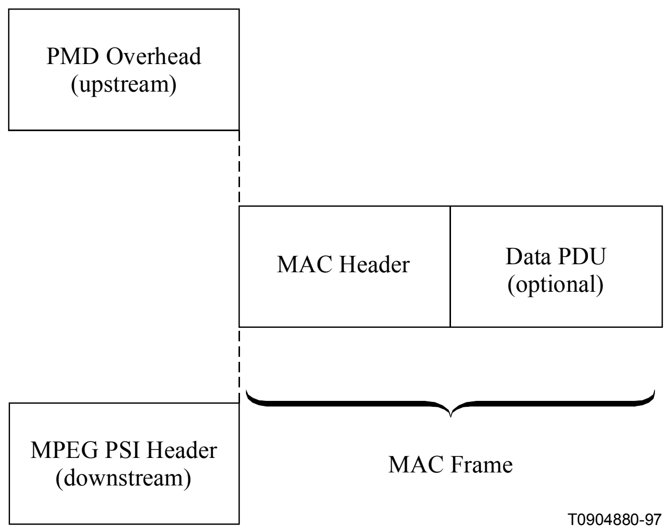


Figure B.6-1/J.116 – Generic MAC frame format

B.6.2.1.1 PMD overhead

In the upstream direction, the PHY layer indicates the start of the MAC frame to the MAC sublayer. From the MAC sublayer's perspective, it only needs to know the total amount of overhead so it can account for it in the Bandwidth Allocation process. More information on this may be found in the PMD Sublayer section of this annex (clause B.4).

The FEC overhead is spread throughout the MAC frame and is assumed to be transparent to the MAC data stream. The MAC sublayer does need to be able to account for the overhead when doing Bandwidth Allocation.

B.6.2.1.2 MAC Frame Transport

The transport of MAC frames by the PMD sublayer for upstream channels is shown in Figure B.6-2.

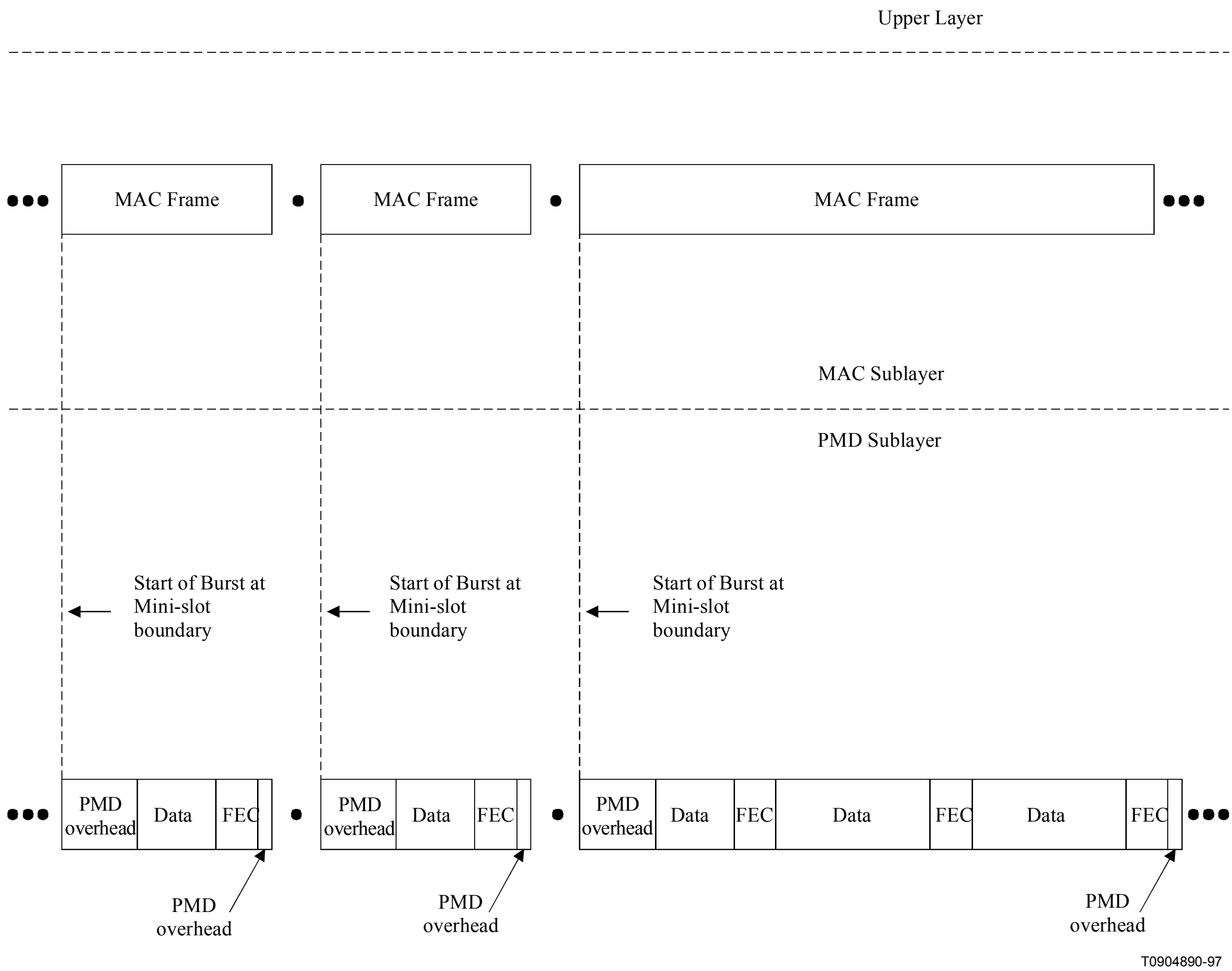


Figure B.6-2/J.116 – Upstream MAC/PMD convergence

The layering of MAC frames over MPEG in the downstream channel is described in clause B.5.

B.6.2.1.3 Ordering of bits and octets

Within an octet, the least-significant bit is the first transmitted on the wire. This follows the convention used by Ethernet and ISO/IEC 8802-3. This is often called bit-little-endian order[4].

Within the MAC layer, when numeric quantities are represented by more than one octet (i.e. 16-bit and 32-bit values), the octet containing the most-significant bits is the first transmitted on the wire. This follows the convention used by TCP/IP and ISO/IEC 8802-3. This is sometimes called byte-big-endian order.

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[4] This applies to the upstream channel only. For the downstream channel, the MPEG transmission convergence sublayer presents an octet-wide interface to the MAC, so the MAC sublayer does not define the bit order.

B.6.2.1.4 MAC header format

The MAC Header format MUST be as shown in Figure B.6-3.

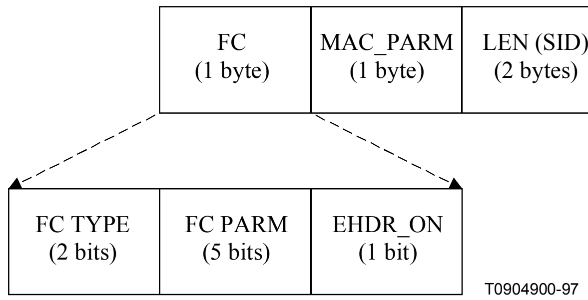

Figure B.6-3/J.116 – MAC header format

All MAC Headers MUST have the general format as shown in Table B.6-1. The Frame Control (FC) field is the first byte and uniquely identifies the rest of the contents within the MAC Header. The FC field is followed by 3 bytes of MAC control; an OPTIONAL Extended Header field (EHDR); plus a Header Check Sequence (HCS) to ensure the integrity of the MAC Header.

Table B.6-1/J.116 – Generic MAC Header Format

MAC Header Field	Usage	Size
FC	Frame Control: Identifies type of MAC Header	8 bits
MAC_PARM	Parameter field whose use is dependent on FC: if EHDR_ON=1; used for EHDR field length (ELEN) else if for concatenated frames (see Table B.6-13) used for MAC frame count else (for Requests only) indicates the number of mini-slots and/or ATM cells requested	8 bits
LEN (SID)	The length of the MAC frame. The length is defined to be the sum of the number of bytes in the extended header (if present) and the number of bytes following the HCS field. (For a REQ Header, this field is the Service ID instead)	16 bits
EHDR	Extended MAC Header (where present; variable size)	0-255 bytes
HCS	MAC Header Check Sequence	2 bytes
	Length of a MAC Header	6 bytes + EHDR

The HCS field is a 16-bit CRC that ensures the integrity of the MAC Header, even in a collision environment. The HCS field coverage MUST include the entire MAC Header, starting with the FC field and including any EHDR field that may be present. The HCS is calculated using ITU-T CRC ($x^{16} + x^{12} + x^5 + 1$) as defined in ITU-T X.25.

The FC field is broken down into the FC_TYPE sub-field, FC_PARM sub-field and an EHDR_ON indication flag. The format of the FC field MUST be as shown in Table B.6-2.

Table B.6-2/J.116 – FC Field Format

FC Field	Usage	Size
FC_TYPE	MAC Frame Control Type field: 00: Packet PDU MAC Header 01: ATM PDU MAC Header 10: Reserved PDU MAC Header 11: MAC Specific Header	2 bits
FC_PARM	Parameter bits, use dependent on FC_TYPE.	5 bits
EHDR_ON	When = 1, indicates that EHDR field is present. Length of EHDR (ELEN) determined by MAC_PARM field	1 bit

The FC_TYPE sub-field is the two MSBs of the FC field. These bits MUST always be interpreted in the same manner to indicate one of four possible MAC frame formats. These types include: MAC Header with Packet PDU; MAC Header with ATM cells; MAC Header reserved for future PDU types; or a MAC Header used for specific MAC control purposes. These types are spelled out in more detail in the remainder of this clause.

The five bits following the FC_TYPE sub-field is the FC_PARM sub-field. The use of these bits are dependent on the type of MAC Header. The LSB of the FC field is the EHDR_ON indicator. If this bit is set, then an Extended Header (EHDR) is present. The EHDR provides a mechanism to allow the MAC Header to be extensible in an inter-operable manner.

The Transmission Convergence Sublayer stuff-byte pattern is defined to be a value of 0xFF. This precludes the use of FC byte values which have FC_TYPE = "11" and FC_PARM = "11111".

The MAC_PARM field of the MAC Header serves several purposes depending on the FC field. If the EHDR_ON indicator is set, then the MAC_PARM field MUST be used as the Extended Header length (ELEN). The EHDR field MAY vary from 0 to 255 bytes. If this is a concatenation MAC Header, then the MAC_PARM field represents the number of MAC frames (CNT) in the concatenation (see B.6.2.5.4). If this is a Request MAC Header (REQ) (see B.6.2.5.3), then the MAC_PARM field represents the amount of bandwidth being requested. In all other cases, the MAC_PARM field is reserved for future use.

The third field has two possible uses. In most cases, it indicates the length (LEN) of this MAC frame. In one special case, the Request MAC Header, it is used to indicate the BWA CPE modem's Service ID since no PDU follows the MAC Header.

The Extended Header (EHDR) field provides extensions to the MAC frame format. It is used to implement data link security and can be extended to add support for additional functions in future releases. Initial implementations SHOULD pass this field to the processor. This will allow future software upgrades to take advantage of this capability. (Refer to B.6.2.6, "Extended MAC Headers" for details.)

B.6.2.1.5 Data PDU

The MAC Header MAY be followed by a Data PDU. The type and format of the Data PDU is defined in the Frame Control field of the MAC Header. The FC field explicitly defines a Packet Data PDU, an ATM Data PDU, a MAC Header only frame (no PDU) and a reserved code point (used as an escape mechanism for future extensions). All BWA CPE modems MUST use the length in the MAC Header to skip over any reserved data.

B.6.2.2 Packet-based MAC frames

B.6.2.2.1 Variable-length packets

The MAC sublayer MUST support a variable-length Ethernet/ISO/IEC 8802-3-type Packet Data PDU. The Packet PDU MAY be passed across the network in its entirety, including its original CRC. A unique Packet MAC Header is appended to the beginning. The frame format without an Extended header MUST be as shown in Figure B.6-4 and Table B.6-3.

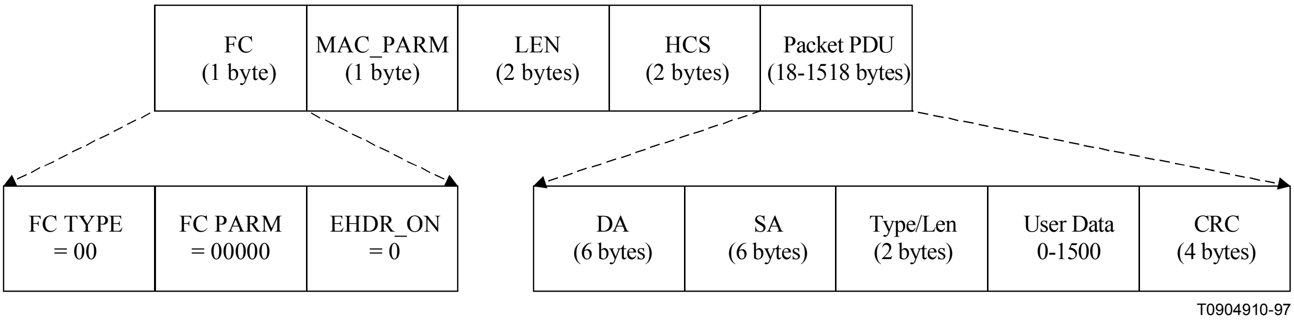

Figure B.6-4/J.116 – Ethernet/802.3 packet PDU format

Table B.6-3/J.116 – Packet PDU format

Field	Usage	Size
FC	FC_TYPE = 00; Packet MAC Header FC_PARM(4) = Data Link Encryption (DLE). If 1 then a security header for data link encryption is present (see B.6.6). If zero then no security header is present. FC_PARM(3:0) = 000; other values reserved for future use and ignored EHDR_ON = 0; no EHDR present in this example	8 bits
MAC_PARM	Reserved, MUST be set to zero if there is no EHDR; otherwise set to length of EHDR	8 bits
LEN	LEN = n; length of Packet PDU in bytes	16 bits
EHDR	Extended MAC Header not present in this example	0 byte
HCS	MAC Header Check Sequence	2 bytes
Packet Data	Packet PDU: DA – 48-bit Destination Address SA – 48-bit Source Address Type/Len – 16-bit Ethernet Type or ISO/IEC 8802-3 Length Field User Data (variable length, 0-1500 bytes) CRC – 32-bit CRC over packet PDU (as defined in Ethernet/ISO/IEC 8802-3)	n bytes
	Length of Packet MAC frame	6 + n bytes

B.6.2.3 ATM cell MAC frames

ATM transport is not defined in this specification.

In order to allow current frame-based BWA CPE modems to operate in a possible future downstream channel in which ATM cells and frames are mixed, a codepoint for ATM has been defined. This will allow current modems to ignore ATM cells while receiving frames. The frame format MUST be as shown in Figure B.6-5 and Table B.6-4.

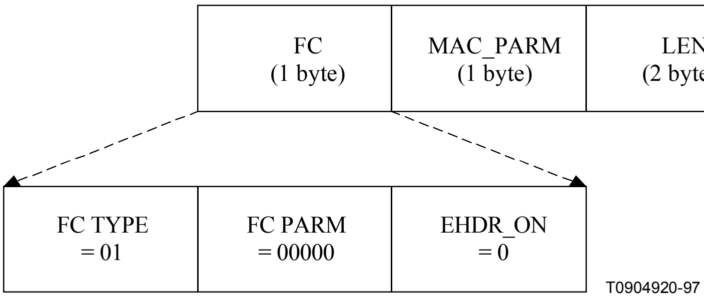

Figure B.6-5/J.116 – ATM cell MAC frame format

Table B.6-4/J.116 – ATM cell MAC frame format

Field	Usage	Size
FC	FC_TYPE = 01; ATM cell format MAC Header FC_PARM(4:0) = 00000; other values reserved for future use and ignored EHDR_ON = 0; no EHDR present in this example	8 bits
MAC_PARM	Reserved, MUST be set to zero if there is no EHDR; otherwise set to length of EHDR	8 bits
LEN	LEN = n × 53; length of ATM cell PDU, in bytes	16 bits
EHDR	Extended MAC Header not present in this example	0 byte
HCS	MAC Header Check Sequence	2 bytes
ATM Data	ATM cell PDU	n × 53 bytes
	Length of ATM cells based MAC frame	6 + n × 53 bytes

B.6.2.4 Reserved PDU MAC frames

The MAC sublayer provides a reserved FC code point to allow for support of future (to be defined) PDU formats. The FC field of the MAC Header indicates that a Reserved PDU is present. This PDU MUST be silently discarded by MAC implementations of this version (1.0) of the specification. Compliant version 1.0 implementations MUST use the length field to skip over the Reserved PDU.

The format of the Reserved PDU without an extended header MUST be as shown in Figure B.6-6 and Table B.6-5.

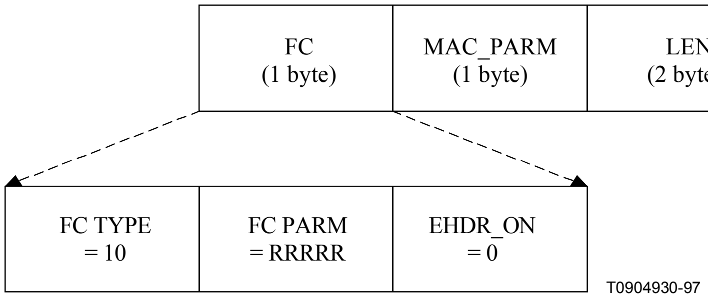

Figure B.6-6/J.116 – Reserved PDU format

Table B.6-5/J.116 – Reserved PDU format

Field	Usage	Size
FC	FC_TYPE = 10; Reserved PDU MAC Header FC_PARM(4:0); reserved for future use EHDR_ON = 0; no EHDR present in this example	8 bits
MAC_PARM	Reserved for future use	8 bits
LEN	LEN = n; length of Reserved PDU in bytes	16 bits
EHDR	EHDR = 0; Extended MAC Header not present in this example	0 byte
HCS	MAC Header Check Sequence	2 bytes
User Data	Reserved Data PDU	n bytes
	Length of a Reserved PDU MAC frame	6 + n bytes

B.6.2.5 MAC-specific Headers

There are several MAC Headers which are used for very specific functions. These functions include support for downstream timing and upstream ranging/power adjust, requesting bandwidth and concatenating multiple MAC frames.

B.6.2.5.1 Timing Header

A specific MAC Header is identified to help support the timing and adjustments required. In the downstream, this MAC Header MUST be used to transport the Global Timing Reference to which all BWA CPE modems synchronise. In the upstream, this MAC Header MUST be used as part of the Ranging message needed for a BWA CPE modem's timing and power adjustments. The Timing MAC Header is followed by a Packet Data PDU. The format MUST be as shown in Figure B.6-7 and Table B.6-6.

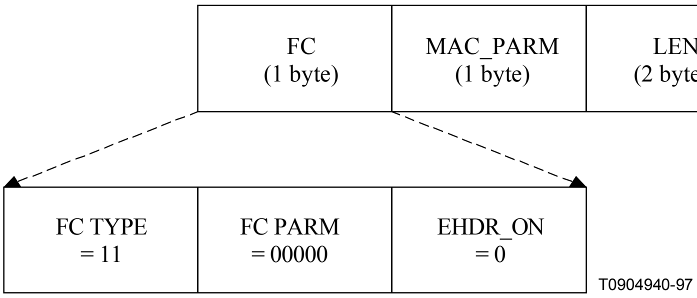

Figure B.6-7/J.116 – Timing MAC Header

Table B.6-6/J.116 – Timing MAC Header format

Field	Usage	Size
FC	FC_TYPE = 11; MAC Specific Header FC_PARM(4:0) = 00000; Timing MAC Header EHDR_ON = 0; extended header prohibited for SYNC and RNG-REQ	8 bits
MAC_PARM	Reserved for future use	8 bits
LEN	LEN = n; length of Packet PDU in bytes	16 bits
EHDR	Extended MAC Header not present	0 byte
HCS	MAC Header Check Sequence	2 bytes
Packet Data	MAC Management message: SYNC message (downstream only) RNG-REQ (upstream only)	n bytes
	Length of Timing Message MAC frame	6 + n bytes

B.6.2.5.2 MAC Management Header

A specific MAC Header is identified to help support the MAC management messages required. This MAC Header MUST be used to transport all MAC management messages (refer to B.6.3). The format MUST be as shown Figure B.6-8 and Table B.6-7.

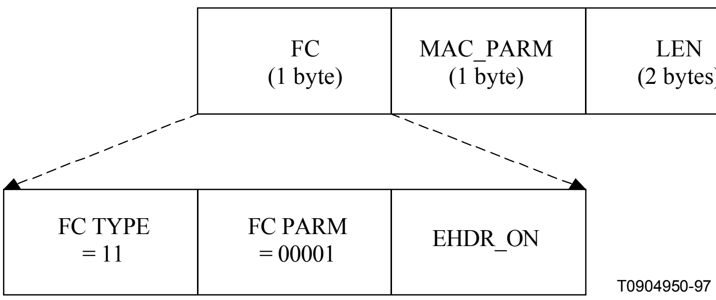

Figure B.6-8/J.116 – Management MAC Header

Table B.6-7/J.116 – Management MAC Header format

Field	Usage	Size
FC	FC_TYPE = 11; MAC Specific Header FC_PARM(4:0) = 00001 EHDR_ON	8 bits
MAC_PARM	Reserved for future use	8 bits
LEN	LEN = n; length of Packet PDU in bytes	16 bits
EHDR	Extended MAC Header not present in this example	0 byte
HCS	MAC Header Check Sequence	2 bytes
Packet Data	MAC Management message:	n bytes
	Length of Management MAC frame	6 + n bytes + EHDR

B.6.2.5.3 Request MAC Header

The Request MAC Header is the basic mechanism that a BWA CPE modem uses to request bandwidth. As such, it is only applicable in the upstream. There MUST be no Data PDUs following the Request MAC Header. The general format of the Request MUST be as shown in Figure B.6-9 and Table B.6-8.

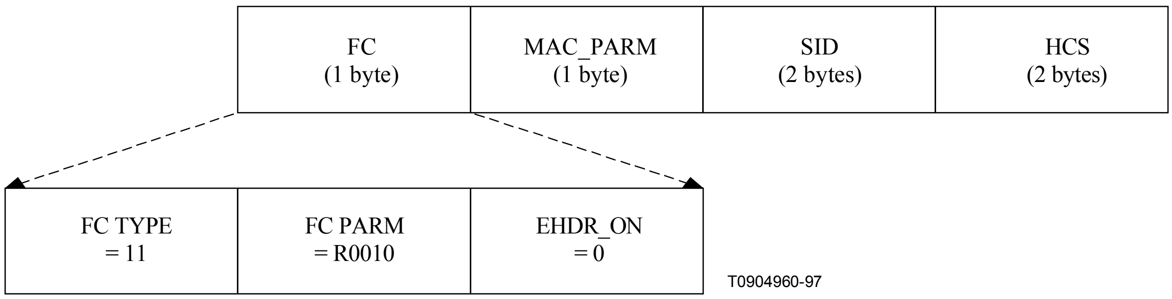

Figure B.6-9/J.116 – Request MAC Header format

Table B.6-8/J.116 – Request MAC Header (REQ) format

Field	Usage	Size
FC	FC_TYPE = 11; MAC-Specific Header FC_PARM(3:0) = 0010; MAC Header only; no data PDU following FC_PARM(4) indicates if REQ is in mini-slots or ATM cells (4) = 0; mini-slot REQ (4) = 1; ATM cell REQ EHDR_ON = 0; no EHDR allowed	8 bits
MAC_PARM	REQ, total amount of bandwidth requested (upstream only): if FC_PARM (4) = 0; REQ is number of mini-slots if FC_PARM (4) = 1; REQ is number of ATM cells	8 bits
SID	Service ID (0 ...0x3FFF)	16 bits
EHDR	Extended MAC Header not allowed	0 byte
HCS	MAC Header Check Sequence	2 bytes
	Length of a REQ MAC Header	6 bytes

Because the Request MAC Header does not have a Data PDU following it, the LEN field is not needed. The LEN field MUST be replaced with an SID. The SID MUST uniquely identify a particular service queue within a given station.

The bandwidth request, REQ, MUST be specified in either mini-slots or in ATM cells. The REQ field MUST indicate the current total amount of bandwidth requested for this service queue.

B.6.2.5.4 Concatenation

A Specific MAC Header is defined to allow multiple MAC frames to be concatenated. This allows a single MAC "burst" to be transferred across the network. The PHY overhead and the Concatenation MAC Header only occur once. Concatenation of multiple MAC frames MUST be as shown in Figure B.6-10.

A compliant BWA BTS Modem and BWA CPE Modem MAY support concatenation.

NOTE – If concatenation is supported, it must be supported on both the upstream and downstream.

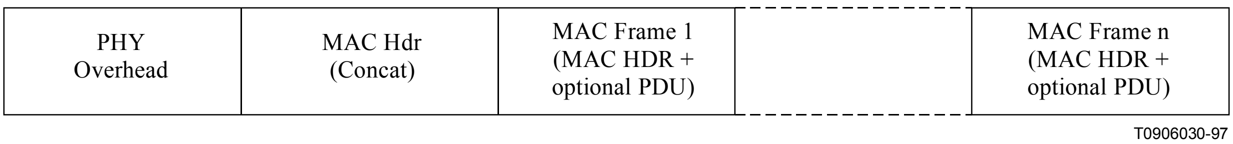

Figure B.6-10/J.116 – Concatenation of multiple MAC frames

Only one Concatenation MAC Header MUST be present per MAC "burst." Nested concatenation MUST NOT be allowed. Immediately following the Concatenation MAC Header MUST be the MAC Header of the first MAC frame. Information within the MAC Header indicates the length of the first MAC Frame and provides a means to find the start of the next MAC Frame. Each MAC frame within a concatenation MUST be unique and MAY be of any type. This means that Packet, ATM, Reserved PDU and MAC-specific Frames MAY be mixed together. The embedded MAC frames MAY be addressed to different destinations and MUST be delivered as if they were transmitted individually.

The format of the Concatenation MAC Header MUST be as shown in Figure B.6-11 and Table B.6-9.

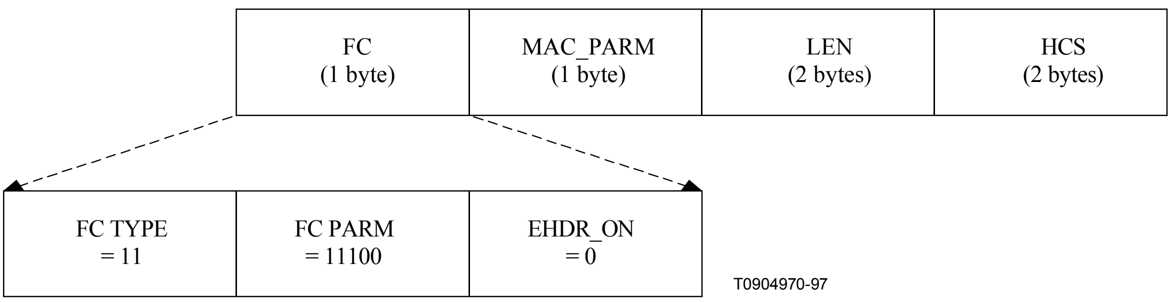

Figure B.6-11/J.116 – Concatenation MAC Header format

Table B.6-9/J.116 – Concatenated MAC frame format

Field	Usage	Size
FC	FC_TYPE = 11; MAC Specific Header FC_PARM(4:0) = 11100; Concatenation MAC Header EHDR_ON = 0; no EHDR with Concatenation Header	8 bits
MAC_PARM	CNT, number of MAC frames in this concatenation CNT = 0 indicates unspecified number of MAC frames	8 bits
LEN	LEN = x + . . . + y; length of all following MAC frames in bytes	16 bits
EHDR	Extended MAC Header MUST NOT be used	0 byte
HCS	MAC Header Check Sequence	2 bytes
MAC frame 1	First MAC frame: MAC Header plus OPTIONAL data PDU	x bytes
MAC frame n	Last MAC frame: MAC Header plus OPTIONAL data PDU	y bytes
	Length of Concatenated MAC frame	6 + LEN bytes

The MAC_PARM field MUST be used to indicate the total count of MAC frames (CNT) in this concatenation burst. If the count equals zero, then there is an unspecified number of MAC frames. The LEN field indicates the length of the entire concatenation. This is slightly different from the LEN field within an individual MAC Header which only indicates the length of that MAC frame.

B.6.2.6 Extended MAC Headers

Every MAC Header, except the Timing, Concatenation MAC Header and Request Frame, has the capability of defining an Extended Header field (EHDR). The presence of an EHDR field MUST be indicated by the EHDR_ON flag in the FC field being set. Whenever this bit is set, then the MAC_PARM field MUST be used as the EHDR length (ELEN). The minimum defined EHDR is 1 byte. The maximum EHDR length is 255 bytes.

A compliant BWA BTS Modem and BWA CPE Modem MUST support extended headers.

The format of a generic MAC Header with an Extended Header included MUST be as shown in Figure B.6-12 and Table B.6-10.

NOTE – Extended Headers MUST NOT be used in a Concatenation MAC Header, but MAY be included as part of the MAC Headers within the concatenation.

Extended Headers MUST NOT be used in Request and Timing MAC Headers.

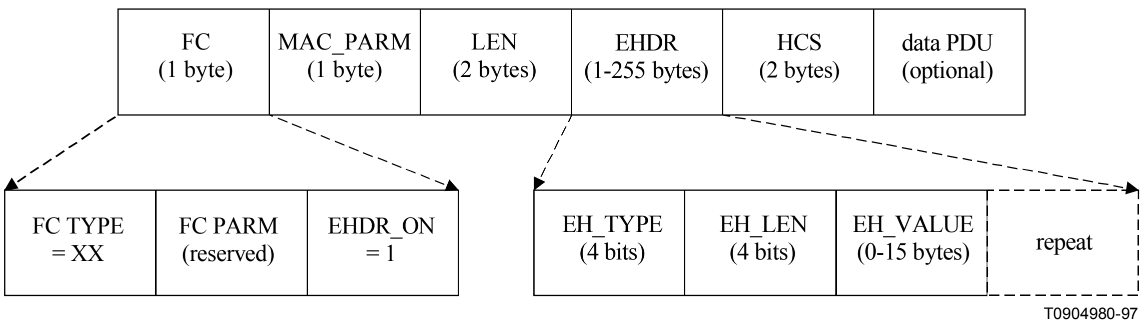

Figure B.6-12/J.116 – Extended MAC format

Table B.6-10/J.116 – Extended Header format

Field	Usage	Size
FC	FC_TYPE = XX; Applies to all MAC Headers FC_PARM(4:0) = XXXXX; dependent on FC_TYPE EHDR_ON = 1; EHDR present in this example	8 bits
MAC_PARM	ELEN = x; length of EHDR in bytes	8 bits
LEN	LEN = x + y; length of EHDR plus OPTIONAL data PDU in bytes	16 bits
EHDR	Extended MAC Header present in this example	x bytes
HCS	MAC Header Check Sequence	2 bytes
PDU	OPTIONAL data PDU	y bytes
	Length of MAC frame with EHDR	6 + x + y bytes

Since the EHDR increases the length of the MAC frame, the LEN field MUST be increased to include both the length of the Data PDU and the length of the EHDR.

The EHDR field consists of one or more EH elements. Each EH element is variable sized. The first byte of the EH element MUST contain a type and a length field. Every BWA CPE Modem MUST use this length to skip over any unknown EH elements. The format of an EH element MUST be as shown in Table B.6-11.

Table B.6-11/J.116 – EH element format

EH element fields	Usage	Size
EH_TYPE	EH element Type Field	4 bits
EH_LEN	Length of EH element	4 bits
EH_VALUE	EH element data	0-15 bytes

The types of EH element defined in Table B.6-12 MUST be supported. Reserved and extended types are undefined at this point and SHOULD be ignored.

The first eight EH element types are intended for one-way transfer between the BWA CPE modem and the BWA BTS modem. The next seven EH element types are for end-to-end usage within a MAC-sublayer domain. Thus, the information attached to the EHDR on the upstream MUST also be attached when the information is forwarded. The final EH element type is an escape mechanism that allows for more types and longer values, and MUST be as shown in Table B.6-12.

Table B.6-12/J.116 – EH element format

EH_TYPE	EH_LEN	EH_VALUE
0	0	Null configuration setting; may be used to pad the extended header. The EH_LEN MUST be zero, but the configuration setting may be repeated.
1	3	Request: mini-slots requested (1 byte); SID (2 bytes) (BWA CPE Modem --> BWA BTS Modem)
2	2	Acknowledgement requested; SID (2 bytes) (BWA CPE Modem -->)
3-7		Reserved (BWA CPE Modem --> BWA BTS Modem)
8	4	Virtual LAN tag (BWA CPE Modem <-> BWA CPE Modem) (Note)
10-14		Reserved (BWA CPE Modem <-> BWA CPE Modem)
15	XX	Extended EH element: EHX_TYPE (1 byte), EHX_LEN (1 byte), EH_VALUE (length determined by EHX_LEN)
NOTE – The format of the 4-byte value is defined in IEEE 802.1Q. Since 802.1Q is under development, this is subject to change to follow that standard.		

B.6.2.7 Error-handling

The BWA network is a potentially harsh environment that may cause several different error conditions to occur. This clause, together with B.7.2.15, describe the procedures that are required when an exception occurs at the MAC framing level.

The most obvious type of error occurs when the HCS on the MAC Header fails. This may be a result of noise on the network or possibly by collisions in the upstream channel. Framing recovery on the downstream channel is performed by the MPEG transmission convergence sublayer. In the upstream channel, framing is recovered on each transmitted burst, such that framing on one burst is independent of framing on prior bursts. Hence, framing errors within a burst are handled by simply ignoring that burst; i.e. errors are unrecoverable until the next burst.

A second exception, which applies only to the upstream, occurs when the Length field is corrupted and the MAC thinks the frame is longer than it actually is. Synchronisation will recover at the next valid upstream data interval.

For Packet PDU transmissions, a bad CRC MAY be detected. Since the CRC only covers the Data PDU and the HCS covers the MAC Header; the MAC Header is still considered valid. Thus, the Packet PDU MUST be dropped, but any pertinent information in the MAC Header (e.g. bandwidth request information) MAY be used.

B.6.3 MAC management messages

B.6.3.1 Message format

MAC management messages MUST be encapsulated in an LLC unnumbered information frame per ISO/IEC 8802-2, which in turn is encapsulated within the BWA network MAC framing, as shown in Figure B.6-13. Figure B.6-13 shows the MAC Header and MAC management header fields which are common across all MAC Messages.

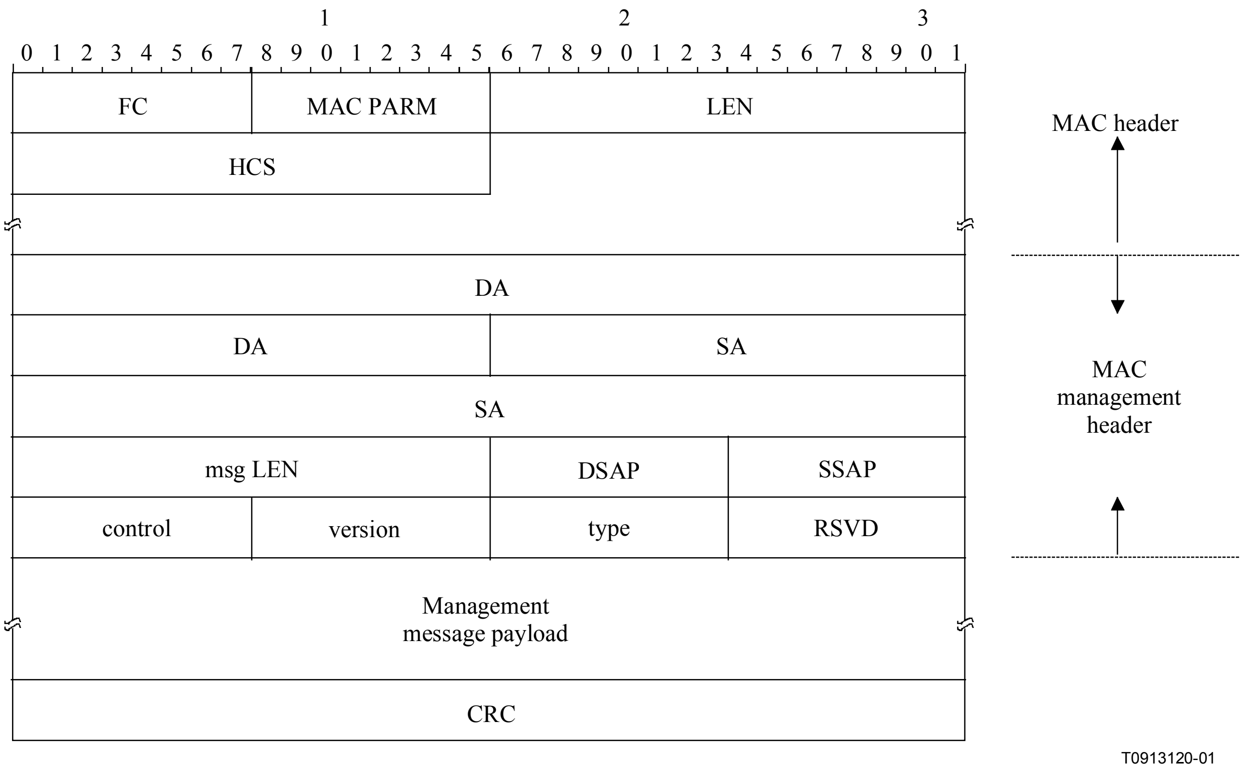

Figure B.6-13/J.116 – MAC Header and MAC Management Header fields

The fields MUST be as defined below:

FC, MAC PARM, LEN, HCS: Common MAC frame header – refer to B.6.2.1.4 for details. All messages use a MAC-specific header.

Destination Address (DA): MAC management frames will be addressed to a specific BWA CPE Modem unicast address or to the BWA management multicast address. These BWA MAC management addresses are described in B.10.

Source Address (SA): The MAC address of the source BWA CPE Modem or BWA BTS Modem system.

Msg Length: The total length of the MAC message from DA to CRC inclusive.

DSAP: The LLC null SAP (00) as defined by ISO/IEC 8802-2.

SSAP: The LLC null SAP (00) as defined by ISO/IEC 8802-2.

Control: Unnumbered information frame (03) as defined by ISO/IEC 8802-2.

Version: 1 octet

This field defines the version of the MAC management protocol in use. Set to 1 for this version.

Type: 1 octet

This field defines the type of this particular MAC management message.

Type value	Message Name	Message Description
1	SYNC	timing synchronisation
2	UCD	upstream channel descriptor
3	MAP	upstream bandwidth allocation
4	RNG-REQ	ranging request
5	RNG-RSP	ranging response
6	REG-REQ	registration request
7	REG-RSP	registration response
8	UCC-REQ	upstream channel change request
9	UCC-RSP	upstream channel change response
10-255		reserved for future use

RSVD: 1 octet

This field is used to align the message payload on a 32-bit boundary. Set to 0 for this version.

Management Message Payload: variable length.

As defined for each specific management message.

CRC: Covers message including header fields (DA, SA, etc.). Polynomial defined by ISO/IEC 8802-3.

B.6.3.2 MAC Management Messages

A compliant BWA BTS Modem or BWA CPE Modem MUST support the following management message types.

B.6.3.2.1 Time Synchronisation (SYNC)

Time Synchronisation (SYNC) MUST be transmitted by BWA BTS Modem at a periodic interval to establish MAC sublayer timing. This message MUST use an FC field of type: Timing. This MUST be followed by a Packet PDU in the format shown in Figure B.6-14.

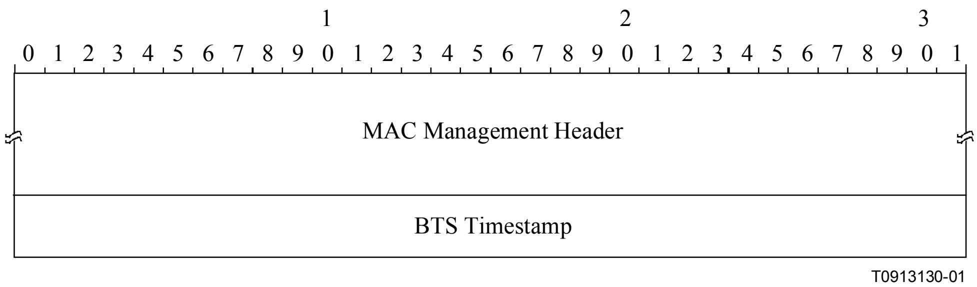

Figure B.6-14/J.116 – Format of packet PDU following the timing header

The parameters shall be as defined below.

BWA BTS Modem Timestamp: An incrementing 32-bit timestamp based on a timebase reference clock at the BWA BTS Modem. Units are in 1/64th of a Timebase Tick (i.e. 6.25/64 μs.[5]).

B.6.3.2.2 Upstream Channel Descriptor (UCD)

An Upstream Channel Descriptor MUST be transmitted by the BWA BTS Modem at a periodic interval to define the characteristics of an upstream channel (Figure B.6-15). A separate message MUST be transmitted for each active upstream.

To provide for flexibility the message parameters following the channel ID MUST be encoded in a type/length/value (TLV) form in which the type and length fields are each 1 octet long. Using this encoding, new parameters MAY be added which not all BWA CPE Modems can interpret. A BWA CPE Modem which does not recognise a parameter type MUST skip over this parameter and MUST NOT treat the event as an error condition.

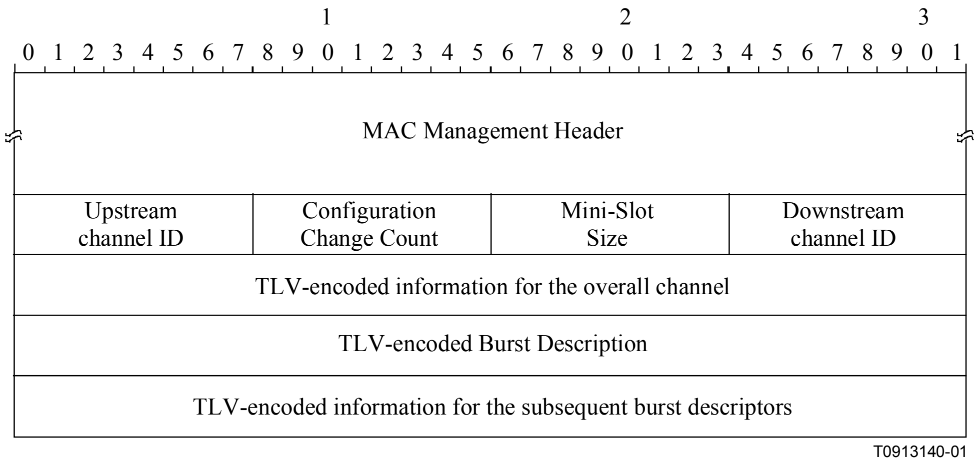

Figure B.6-15/J.116 – Upstream Channel Descriptor

A BWA BTS Modem MUST generate UCDs in the format shown in Figure B.6-15, including all of the following parameters:

Configuration Change Count: Incremented by one (modulo the field size) by the BWA BTS Modem whenever any of the values of this channel descriptor change. If the value of this count in a subsequent UCD remains the same, the BWA CPE Modem can quickly decide that the remaining fields have not changed, and may be able to disregard the remainder of the message. This value is also referenced from the MAP.

Mini-Slot Size: The size of the Mini-Slot for this upstream channel in units of the Timebase Tick (see SYNC message).

upstream channel ID: The identifier of the upstream channel to which this message refers. This identifier is arbitrarily chosen by the BWA BTS Modem and is only unique within the MAC-Sublayer domain.

---

[5] Since the SYNC message applies to all upstream channels within this MAC domain, units were chosen to be independent of the symbol rate of any particular upstream channel. A timebase tick represents the smallest possible mini-slot at the highest possible symbol rate. See B.6.5.4 for time-unit relationships.

downstream channel ID: The identifier of the downstream channel on which this message has been transmitted. This identifier is arbitrarily chosen by the BWA BTS Modem and is only unique within the MAC-Sublayer domain.

All other parameters are coded as TLV tuples. Channel-wide parameters (types 1-3 in Table B.6-13) must precede burst descriptors (type 4 below).

Table B.6-13/J.116 – Channel TLV parameters

Name	Type (1 byte)	Length (1 byte)	Value (Variable length)
Symbol Rate	1	1	1-32; multiples of base rate of 160 ksym/s
Frequency	2	4	Upstream centre frequency (Hz)
Preamble Pattern	3	1-128	Preamble superstring. All burst-specific preamble values are chosen as bit-substrings of this string.
Burst Descriptor	4		May appear more than once; described below. The length is the number of bytes in the overall object, including embedded TLV items.

Burst Descriptors are compound TLV encodings that define, for each type of upstream usage interval, the physical-layer characteristics that are to be used during that interval. The upstream interval usage codes are defined in the MAP message (see B.6.3.2.3 and Table B.6-15).

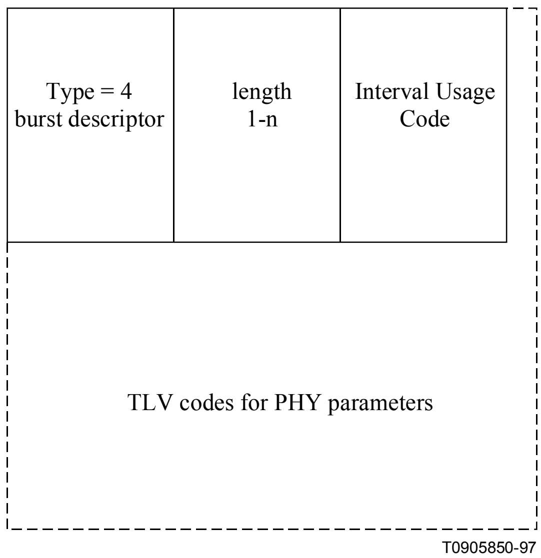

Figure B.6-16/J.116 – Top-level encoding for a Burst Descriptor

A Burst Descriptor MUST be included for each interval usage code that is to be used in the allocation MAP. The interval usage code above must be one of the values from Table B.6-15.

Within each Burst Descriptor is an unordered list of Physical-layer attributes, encoded as TLV values. These attributes are shown in Table B.6-14.

Table B.6-14/J.116 – Upstream Physical-Layer Burst Attributes

Name	Type (1 byte)	Length (1 byte)	Value (Variable Length)
Modulation Type	1	1	1 = QPSK, 2 = 16-QAM
Differential Encoding	2	1	1 = on, 2 = off
Preamble Length	3	2	Up to 1024 bits. The value must be an integral number of symbols (a multiple of 2 for QPSK and 4 for 16-QAM)
Preamble Value Offset	4	2	Identifies the bits to be used for the preamble value. This is specified as a starting offset into the Preamble Pattern (see Table B.6-13). That is, a value of zero means that the first bit of the preamble for this burst type is the value of the first bit of the Preamble Pattern. A value of 100 means that the preamble is to use the 101st and succeeding bits from the Preamble Pattern. This value must be a multiple of the symbol size.
FEC Error Correction (T bytes)	5	1	0-10 bytes. Zero implies no Forward Error Correction.
FEC Codeword Length (k)	6	1	Fixed: 1 to 255 Shortened: 16 to 255
Scrambler Seed	7	2	The 15-bit seed value.
Maximum Burst Size	8	1	The maximum number of mini-slots that can be transmitted during this burst type. Absence of this configuration setting implies that the burst size is limited elsewhere. This value MUST be used when the interval type is Short Data Grant.
Guard Time Size	9	1	Number of symbol times which must follow the end of this burst. (Although this value may be derivable from other network and architectural parameters, it is included here to ensure that the BWA CPE Modems and BWA BTS Modem all use the same value.)
Last Codeword Length	10	1	1 = fixed; 2 = shortened
Scrambler on/off	11	1	1 = on; 2 = off

B.6.3.2.2.1 Example of UCD Encoded TLV data

An example of UCD encoded TLV data is given in Figure B.6-17.

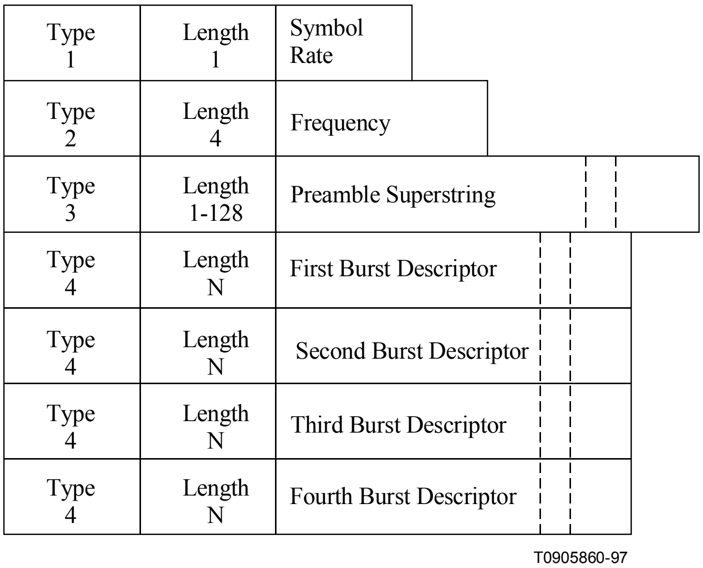

Figure B.6-17/J.116 – Example of UCD encoded TLV data

B.6.3.2.3 Upstream Bandwidth Allocation Map (MAP)

A BWA BTS Modem MUST generate MAPs in the format shown in Figure B.6-18.

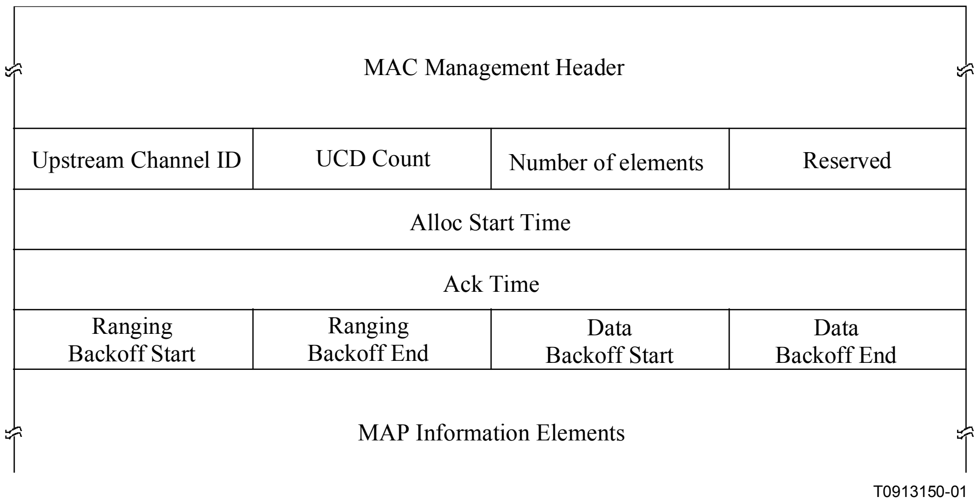

Figure B.6-18/J.116 – MAP format

The parameters MUST be as follows:

Channel ID: The identifier of the upstream channel to which this message refers.

UCD Count: Matches the value of the Configuration Change Count of the UCD which describes the burst parameters which apply to this map. See B.7.2.13.

Number Elements: Number of information elements in the map.

RSVD: Reserved field for alignment.

Alloc Start time: Effective start time from BWA BTS Modem initialisation (in mini-slots) for assignments within this map.

Ack time: Latest time, from BWA BTS Modem initialisation, (mini-slots) processed in upstream that generated a Grant, Grant Pending or Data Ack.

Ranging Backoff Start: Initial back-off window for initial ranging contention, expressed as a power of two. Values range 0-15.

Ranging Backoff End: Final back-off window for initial ranging contention, expressed as a power of two. Values range 0-15.

Data Backoff Start: Initial back-off window for contention data and requests, expressed as a power of two. Values range 0-15.

Data Backoff End: Final back-off window for contention data and requests, expressed as a power of two. Values range 0-15.

MAP information elements: MUST be in the format defined in Figure B.6-19 and Table B.6-15. Values for IUCs are defined in Table B.6-15 and are described in detail in B.6.4.1.

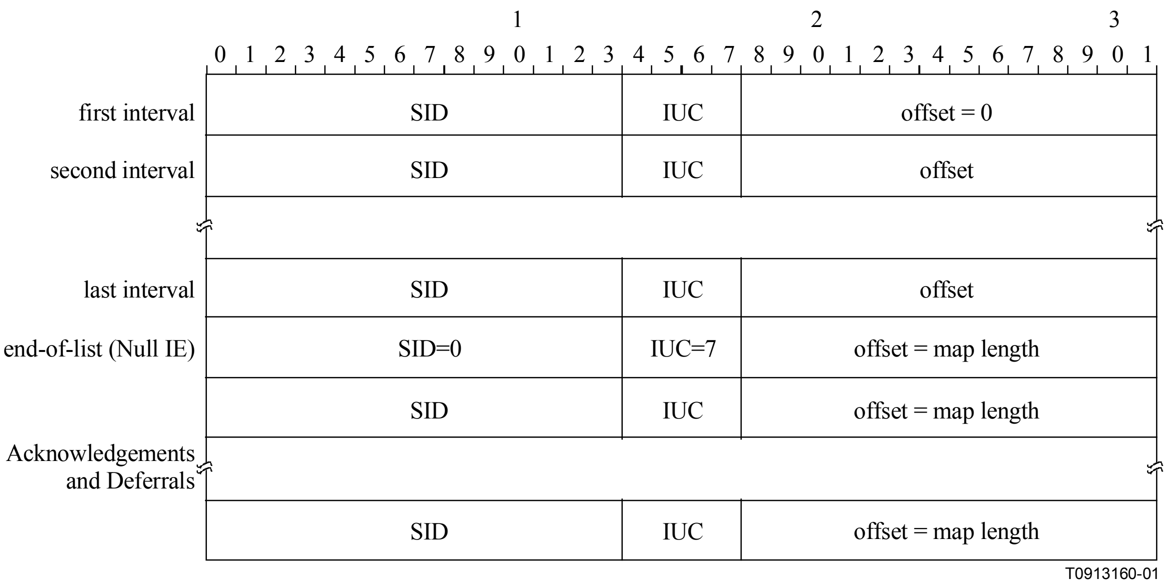

Figure B.6-19 /J.116 – MAP information element structure

Table B.6-15/J.116 – Allocation MAP Information Elements (IE)

IE Name	Interval Usage Code (IUC) (4 bits)	SID (14 bits)	Mini-slot Offset (14 bits)
Request	1	Any	Starting offset of REQ region
REQ/Data (refer to B.10 for multicast definition)	2	Multicast	Starting offset of IMMEDIATE Data region well-known multicasts define start intervals
Initial Maintenance	3	Broadcast/ multicast	Starting offset of MAINT region (used in Initial Ranging)
Station Maintenance (Note 1)	4	Unicast	Starting offset of MAINT region (used in Periodic Ranging)
Short Data Grant (Note 2)	5	Unicast	Starting offset of Data Grant assignment; if inferred length = 0, then it is a Data Grant pending.
Long Data Grant (Note 2)	6	Unicast	Starting offset of Data Grant assignment; if inferred length = 0, then it is a Data Grant Pending
Null IE	7	Zero	Ending offset of the previous grant. Used to bound the length of the last actual interval allocation.
Data Ack	8	Unicast	BWA BTS Modem sets to 0
Reserved	9-14	Any	Reserved
Expansion	15	Expanded IUC	# of additional 32-bit words in this IE

NOTE 1 – Although the distinction between Initial Maintenance and Station Maintenance is unambiguous from the Service ID type, separate codes are used to ease physical-layer configuration (see burst descriptor encodings, Table B.6-14).

NOTE 2 – The distinction between long and short data grants is related to the amount of data that can be transmitted in the grant. A short data grant interval may use FEC parameters that are appropriate to short packets while a long data grant may be able to take advantage of greater FEC coding efficiency.

B.6.3.2.4 Ranging Request (RNG-REQ)

A Ranging Request MUST be transmitted by a BWA CPE Modem at initialisation and periodically on request from BWA BTS Modem to determine network delay. This message MUST use an FC field of type: Timing. This MUST be followed by a Packet PDU in the format shown in Figure B.6-20.

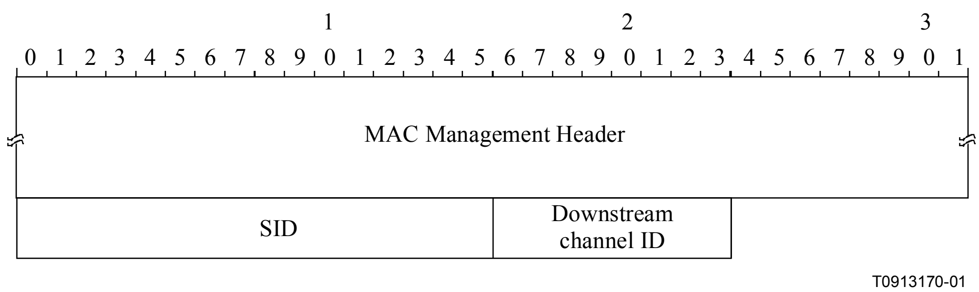

Figure B.6-20/J.116 – Packet PDU following the Timing Header

Parameters MUST be as follows:

SID: Initialisation SID or assigned SID for periodic requests (this is a 16-bit field of which the lower 14 bits define the SID with bits 14, 15 defined to be 0).

Downstream channel ID: The identifier of the downstream channel on which the BWA CPE Modem received the UCD which described this upstream. This is an 8-bit field.

B.6.3.2.5 Ranging Response (RNG-RSP)

A Ranging Response MUST be transmitted by a BWA BTS Modem in response to received RNG-REQ in the format shown in Figure B.6-21. The state machines describing the ranging procedure appear in B.7.2.4. In that procedure it may be noted that, from the point of view of the BWA CPE Modem, reception of a Ranging Response is stateless. In particular, the BWA CPE Modem MUST be prepared to receive a Ranging Response at any time, not just following a Ranging Request.

To provide for flexibility, the message parameters following the Upstream Channel ID MUST be encoded in a type/length/value (TLV) form. Using this encoding, new parameters MAY be added which not all BWA CPE Modems can interpret. A BWA CPE Modem which does not recognise a parameter type MUST simply skip over this parameter and MUST NOT treat the event as an error condition.

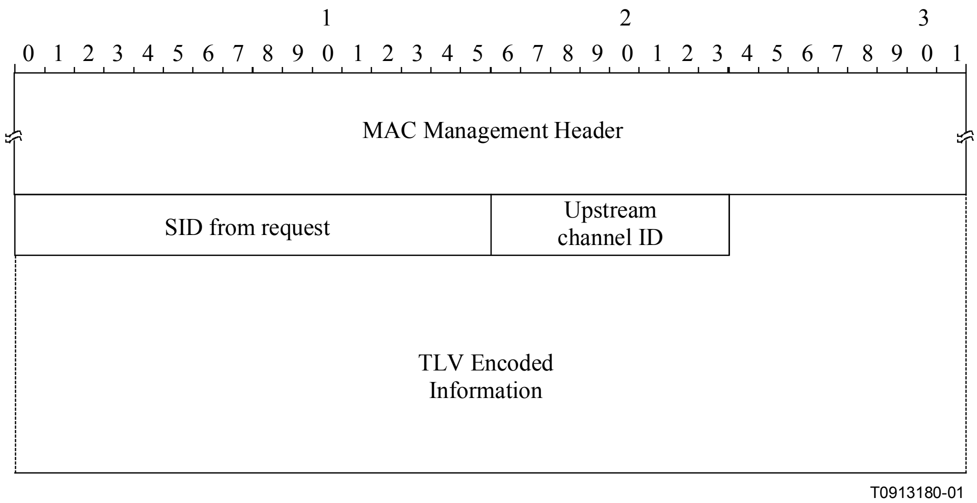

Figure B.6-21/J.116 – Ranging Response

Parameters MUST be as follows:

SID: SID from corresponding RNG-REQ to which this response refers.

Upstream channel ID: The identifier of the upstream channel on which the BWA BTS Modem received the RNG-REQ to which this response refers.

Timing adjust information: The time by which to offset frame transmission so that frames arrive at the expected mini-slot time at the BWA BTS Modem.

Power adjust information: Specifies the relative change in transmission power level that the BWA CPE Modem is to make in order that transmissions arrive at the BWA BTS Modem at the desired power.

Frequency adjust information: Specifies the relative change in transmission frequency that the BWA CPE Modem is to make in order to better match the BWA BTS Modem. (This is fine-frequency adjustment within a channel, not re-assignment to a different channel.)

BWA CPE Modem transmitter equalisation information: If the BWA CPE Modem implements transmission equalisation, this provides the equalisation coefficients.

Ranging status: Used to indicate whether upstream messages are received within acceptable limits by BWA BTS modem.

B.6.3.2.5.1 Encodings

The type values used MUST be those defined in Table B.6-16 and Figure B.6-22. These are unique within the ranging response message but not across the entire MAC message set. The type and length fields MUST each be 1 octet in length.

Table B.6-16/J.116 – Ranging response message encodings

Name	Type (1 byte)	Length (1 byte)	Value (Variable Length)
Timing Adjust	1	4	TX timing offset adjustment (signed 16-bit, units of (6.25 microsec/64))
Power Level Adjust	2	1	TX Power offset adjustment (signed 8-bit, 1/4 dB units)
Offset Frequency Adjust	3	2	TX frequency offset adjustment (signed 16-bit, Hz units)
Transmit Equalisation Adjust	4	n	TX equalisation data – see details below
Ranging Status	5	1	1 = continue, 2 = abort, 3 = success
Reserved	6-255	n	Reserved for future use

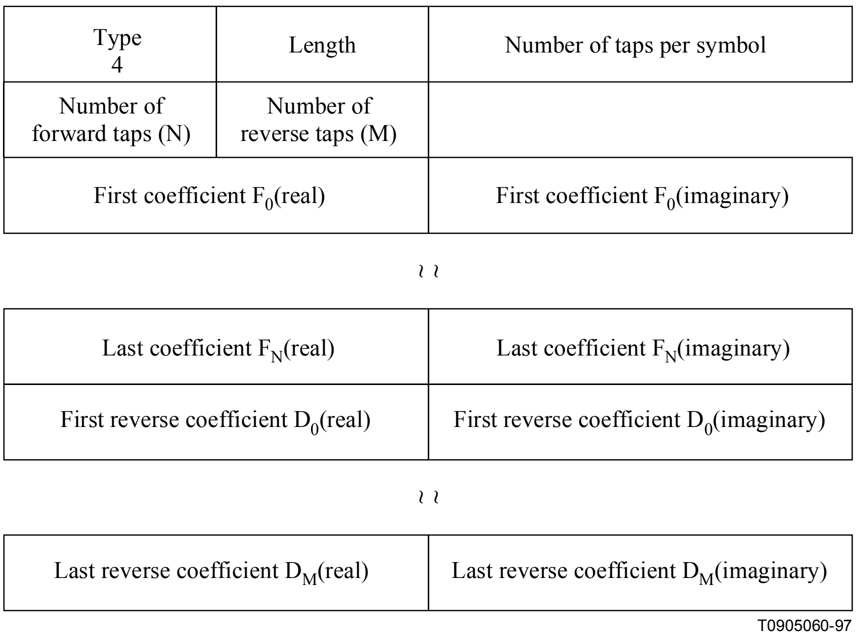

Figure B.6-22/J.116 – Generalised decision feedback equalisation coefficients

The total number of taps per symbol MUST be in the range 1 to 4.

The total number of taps MAY range up to 64. Each tap consists of a real and imaginary coefficient entry in the table.

If more than 255 bytes are needed to represent equalisation information, then several type-4 elements MAY be used. Data MUST be treated as if byte-concatenated, that is, the first byte after the length field of the second type-4 element is treated as if it immediately followed the last byte of the first type-4 element.

The coefficients that are sent to the BWA CPE Modem are actually coefficients of a BWA BTS Modem demodulator equaliser, which, after acquisition, will have tap values which represent the channel distortion. Figure B.6-23 defines these taps. After receiving these tap values, the BWA CPE Modem must decide the best way to use this information to configure its transmit equaliser. This is a vendor-specific issue, if implemented[6], which is not described here.

Other equalisation methods may be devised in the future. If so, they will use a different type-value so that this element is not overloaded.

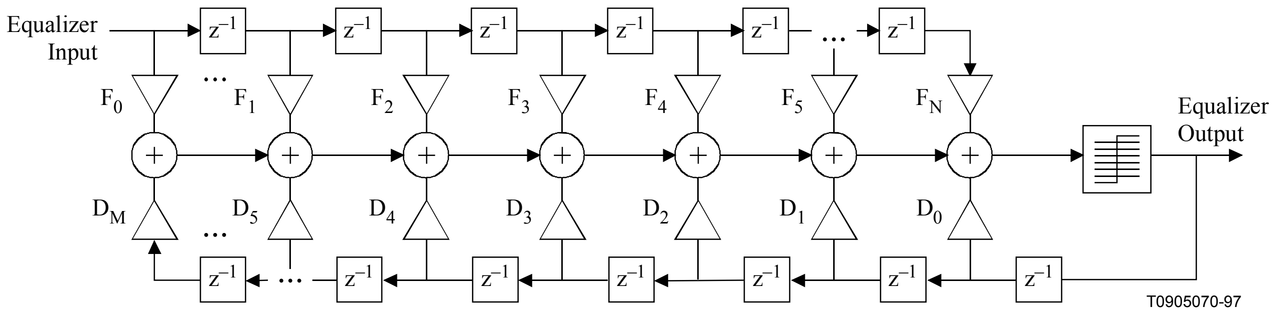

Figure B.6-23/J.116 – BWA BTS Modem Demodulator Equaliser Tap Location Definition

B.6.3.2.5.2 Example of TLV data

An example of TLV data is given in Figure B.6-24.

Type 1	Length 4	Timing adjust
Type 2	Length 1	Power adjust
Type 3	Length 2	Frequency adjust information
Type 4	Length x	x bytes of CM transmitter equalisation information
Type 5	Length 1	Ranging status

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Figure B.6-24/J.116 – Example of TLV data

6 Implementation details will depend on the specific application and an equaliser may not always be needed.

B.6.3.2.6 Registration Request (REG-REQ)

A Registration Request, in the format shown in Figure B.6-25, MUST be transmitted by a BWA CPE Modem at initialisation after receipt of a BWA CPE Modem parameter file.

To provide for flexibility, the message parameters following the SID MUST be encoded in a type/length/value form. Using this encoding, new parameters MAY be added which not all BWA BTS Modems can interpret. A BWA BTS Modem which does not recognise a parameter type MUST simply skip over this parameter and MUST not treat the event as an error condition.

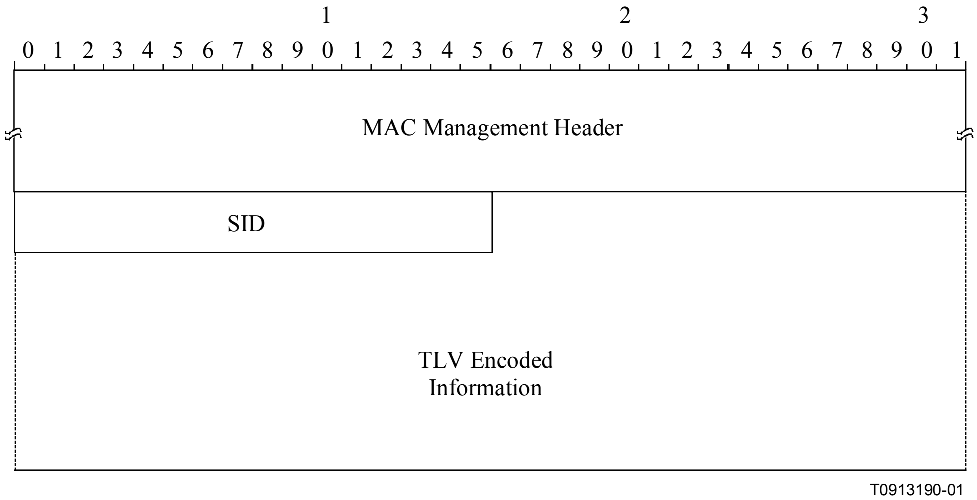

Figure B.6-25/J.116 – Registration Request

Parameters MUST be as follows:

SID: Initialisation SID for this BWA CPE Modem.

Configuration Settings for this modem: As defined in B.12:

- Downstream Frequency Configuration Setting.
- Upstream Channel ID Configuration Setting.
- Network Access Configuration Setting.
- Class of Service Configuration Setting.
- Modem Capabilities Configuration Setting.
- Modem IP address.

NOTE 1 – The BWA CPE Modem MUST be capable of supporting these standard configuration settings.

Vendor-specific data: As defined in B.12:

- Vendor ID Configuration Setting (vendor ID of BWA CPE Modem).
- Vendor-specific extensions.

Message Integrity Checks: As defined in B.12:

- BWA CPE Modem MIC Configuration Setting.
- BWA BTS Modem MIC Configuration Setting.

NOTE 2 – The BWA CPE Modem MUST forward the vendor-specific data to the BWA BTS Modem in the same order in which they were received in the configuration file, to allow the message integrity check to be performed.

B.6.3.2.6.1 Encodings

The type values used are unique within the registration request message but not across the entire MAC message set. They MUST be those defined in B.12.

NOTE – The BWA CPE Modem MUST forward the vendor specific configuration settings to the BWA BTS Modem in the same order in which they were received in the configuration file to allow the message integrity check to be performed.

B.6.3.2.6.2 Example

An example of type value encodings is given in Figure B.6-26.

Type 1	Length 4	Downstream Frequency
Type 2	Length 1	Upstream channel
Type 3	Length 1	Network access
Type 4	Length 28	Service class definition class 1
Type 4	Length 28	Service class definition class 2
Type 4	Length 28	Service class definition class n
Type 5	Length 3	Modem capabilities
Type 12	Length 4	Modem IP address
Type 8	Length 3	Vendor ID
Type 43	Length n	n bytes of vendor-specific data
Type 6	Length 16	CM message integrity check
Type 7	Length 16	CMTS message integrity check

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Figure B.6-26/J.116 – Example of Registration Request Type Value Encodings

B.6.3.2.7 Registration Response (REG-RSP)

A Registration Response, in the format shown in Figure B.6-27, MUST be transmitted by BWA BTS Modem in response to received REG-REQ.

To provide for flexibility, the message parameters following the SID MUST be encoded in a type/length/value form. Using this encoding, new parameters MAY be added which not all BWA CPE Modems can interpret. A BWA CPE Modem which does not recognise a parameter type MUST skip over this parameter and MUST NOT treat the event as an error condition.

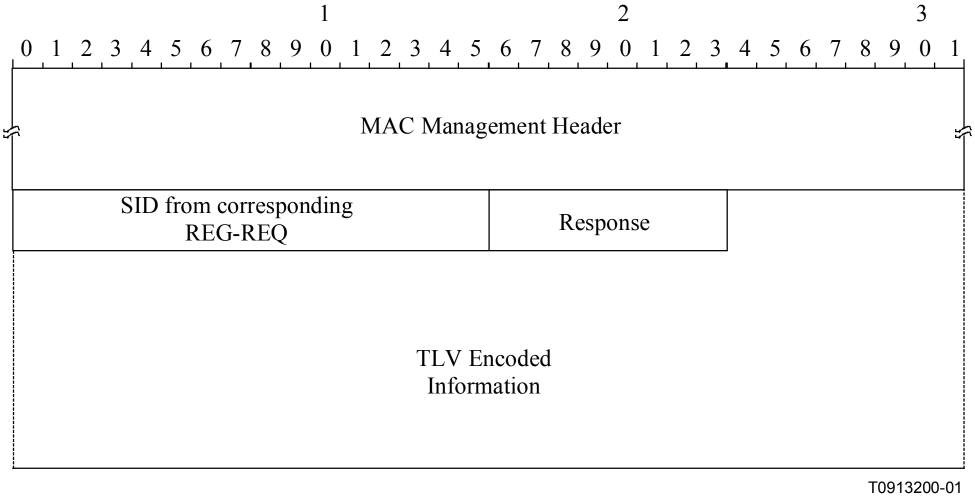

Figure B.6-27/J.116 – Registration Response Format

Parameters MUST be as follows:

SID from Corresponding REG-REQ:	SID from corresponding REG-REQ to which this response refers.
Response:	0 = ok. 1 = authentication failure. 2 = class of service failure.
CPE Modem Capabilities:	The BWA BTS Modem response to the capabilities of the modem.
Service Class Data:	Returned when Response = ok. Service ID/service class tuple for each class of service granted.
Service Not Available:	Returned when Response = class of service failure. If a service class cannot be supported, this configuration setting is returned in place of the service class data. If this is received, the entire registration request is considered to have failed and must be repeated.
Vendor-Specific Data	As defined in B.12:

- Vendor ID Configuration Setting (vendor ID of BWA BTS modem).
- Vendor-specific extensions.

NOTE 1 – Service class IDs MUST be those requested in the corresponding REG-REQ.

NOTE 2 – The initialisation SID MUST no longer be used once the REG-RSP is received.

B.6.3.2.7.1 Encodings

The type values used MUST be those shown below. These are unique within the registration response message but not across the entire MAC message set. The type and length fields MUST each be 1 octet.

B.6.3.2.7.1.1 CPE Modem Capabilities

This field defines the BWA BTS Modem response to the CPE modem capability field in the Registration Request. The BWA BTS Modem responds to the CPE modem capabilities to indicate whether they may be used. If the BWA BTS Modem does not recognise a CPE modem capability, it must return this as "off" in the Registration Response.

Only capabilities set to "on" in the REG-REQ may be set "on" in the REG-RSP as this is the handshake indicating that they have been successfully negotiated.

Encodings are as defined for the Registration Request.

B.6.3.2.7.1.2 Service Class Data

This encoding defines the parameters associated with a requested class of service. It is somewhat complex in that it is composed of a number of encapsulated type/length/value fields. The encapsulated fields define the particular class of service parameters for the class of service in question. Note that the type fields defined are only valid within the encapsulated service class data configuration setting string. A single service class data configuration setting MUST be used to define the parameters for a single service class. Multiple class definitions MUST use multiple service class data configuration setting sets.

type	length	value
1	n	encoded service class data

Internal service class data encodings

Class ID

The value of the field MUST specify the identifier for the class of service to which the encapsulated string applies. This MUST be a class which was requested in the associated REG-REQ.

type	length	value
1	1	from REG-REQ

Valid Range

The class ID MUST be in the range 1 to 16.

Service ID

The value of the field MUST specify the SID associated with this service class.

type	length	value
2	2	SID

B.6.3.2.7.2 Registration Response Encoding Example

An example of Registration Response encoding is given in Figure B.6-28.

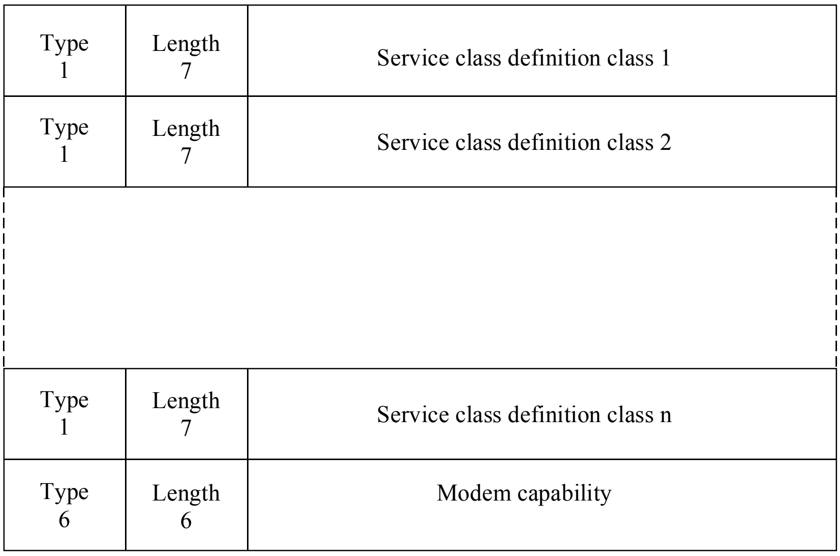

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Figure B.6-28/J.116 – Example of Registration Response Encoding

B.6.3.2.7.3 Sample Service Class Data Encoding

Sample service class data encodings are provided in Table B.6-17.

Table B.6-17/J.116 – Sample Service Class Data Encoding

Type	Length	VALUE (sub)type	Length	Value	Description
1	7				Service class data configuration setting
		1	1	1	Service class 1
		2	2	123	SID for this class
1	7				Service class data configuration setting
		1	1	2	Service class 2
		2	2	244	SID for this class
1	7				Service class data configuration setting
		1	1	n	Service class n
		2	2	345	SID for this class

B.6.3.2.8 Upstream Channel Change Request (UCC-REQ)

An Upstream Channel Change Request MAY be transmitted by a BWA BTS Modem to cause a BWA CPE Modem to change the upstream channel on which it is transmitting. The format of an UCC-REQ message is shown in Figure B.6-29.

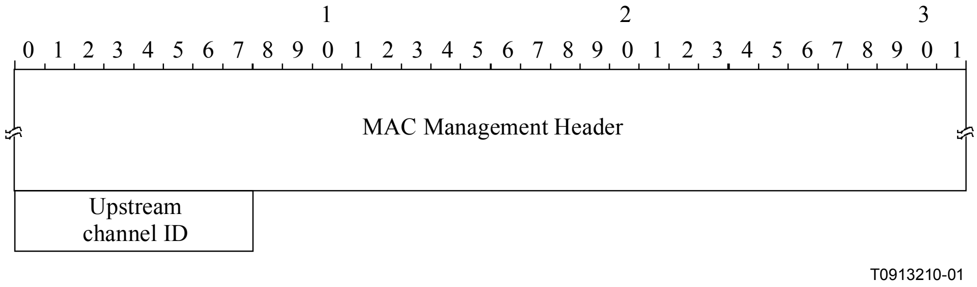

Figure B.6-29/J.116 – Upstream Channel Change Request

Parameters MUST be as follows:

Upstream channel ID

The identifier of the upstream channel to which the BWA CPE Modem is to switch for upstream transmissions. This is an 8-bit field.

B.6.3.2.9 Upstream Channel Change Response (UCC-RSP)

An Upstream Channel Change Response MUST be transmitted by a BWA CPE Modem in response to a received Upstream Channel Change Request message to indicate that it has received and is complying with the UCC-REQ. The format of an UCC-RSP message is shown in Figure B.6-30.

Before it begins to switch to a new upstream channel, a BWA CPE Modem MUST transmit a UCC-RSP on its existing upstream channel. A BWA CPE Modem MAY ignore an UCC-REQ message while it is in the process of performing a channel change. When a BWA CPE Modem receives a UCC-REQ message requesting that it switch to an upstream channel that it is already using, the BWA CPE Modem MUST respond with a UCC-RSP message on that channel indicating that it is already using the correct channel.

To switch to a new upstream channel, a BWA CPE Modem will begin a new ranging procedure for that channel, and upon completion of ranging will proceed without re-performing registration. The full procedure for changing channels is described in B.7.2.14.

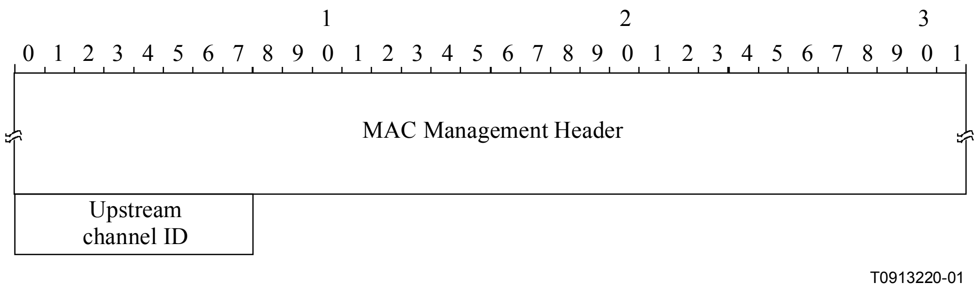

Figure B.6-30/J.116 – Upstream Channel Change Response

Parameters MUST be as follows:

Upstream channel ID

The identifier of the upstream channel to which the BWA CPE Modem is to switch for upstream transmissions. This is the same Channel ID specified in the UCC-REQ message. This is an 8-bit field.

B.6.4 Upstream Bandwidth Allocation

The upstream channel is modelled as a stream of mini-slots. The BWA BTS Modem MUST generate the time reference for identifying these slots. It MUST also control access to these slots by the BWA CPE modems. For example, it MAY grant some number of contiguous slots to a BWA CPE Modem for it to transmit a data PDU. The BWA CPE Modem MUST time its transmission so that the BWA BTS Modem receives it in the time reference specified. This clause describes the elements of protocol used in requesting, granting, and using upstream bandwidth. The basic mechanism for assigning bandwidth management is the allocation map. Please refer to Figure B.6-31.

The allocation map is a MAC Management message transmitted by the BWA BTS Modem on the downstream channel which describes, for some interval, the uses to which the upstream mini-slots MUST be put. A given map MAY describe some slots as grants for particular stations to transmit data in, other slots as available for contention transmission, and other slots as an opportunity for new stations to join the link.

Many different scheduling algorithms MAY be implemented in the BWA BTS Modem by different vendors; this specification does not mandate a particular algorithm. Instead, it describes the protocol elements by which bandwidth is requested and granted.

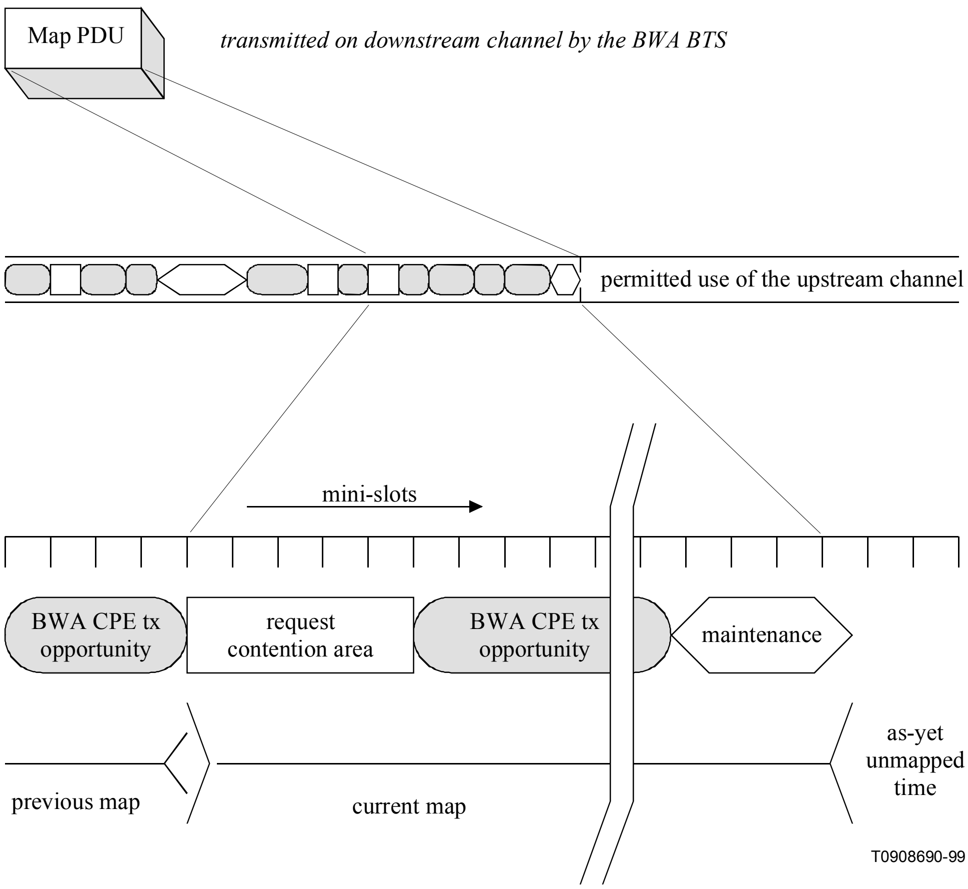

Figure B.6-31/J.116 – Allocation Map

The bandwidth allocation MUST include the following basic elements:

- Each BWA CPE Modem has one or more short (14-bit) service identifiers as well as a 48-bit address.
- Upstream bandwidth is divided into a stream of mini-slots. Each mini-slot is numbered relative to a master reference maintained by the BWA BTS Modem. The clocking information is distributed to the BWA CPE Modems by means of SYNC packets.
- BWA CPE Modems MAY issue requests to the BWA BTS Modem for upstream bandwidth.

The BWA BTS Modem MUST transmit allocation map PDUs on the downstream channel defining the allowed usage of each mini-slot. The map is described below.

B.6.4.1 The Allocation Map MAC Management Message

The allocation map is a varying-length MAC Management message that is transmitted by the BWA BTS Modem to define transmission opportunities on the upstream channel. It includes a fixed-length header followed by a variable number of information elements (IEs) in the format shown in B.6.3.2.3. Each information element defines the allowed usage for a range of mini-slots.

The fixed header includes the following (see also Figure B.6-18):

- An 8-bit upstream channel identifier. This allows multiple upstream channels to be associated with a single downstream channel (Multiple upstream/downstream channel issues MAY be addressed by vendors in a variety of ways, and are beyond the scope of this specification).
- (8 bits) the number of Information Elements which follow.
- (16 bits) reserved for future use.
- The effective start time of the first entry in this map. This is expressed as a 32-bit mini-slot counter. The time reference is distributed separately by the SYNC PDUs. Note that the Map PDU MUST be transmitted in advance of its effective start time in order to allow BWA CPE Modems to receive and process it (see B.6.4.2).
- The latest time for which responses to upstream requests are included in this MAP.

B.6.4.1.1 Information Elements

Each IE consists of a 14-bit Service ID, a 4-bit type code, and a 14-bit starting offset as defined in B.6.3.2.3. Since all stations MUST scan all IEs, it is critical that IEs be short and relatively fixed format. IEs within the map are strictly ordered by starting offset. For most purposes, the duration described by the IE is inferred by the difference between the IE's starting offset and that of the following IE. For this reason, a null IE MUST terminate the list. Refer to Table B.6-15.

Four types of Service IDs are defined:

1) 0x3FFF – broadcast, intended for all stations.
2) 0x2000-0x3FFE – multicast, purpose is defined administratively. See B.10.
3) 0x0001-0x1FFF – unicast, intended for a particular BWA CPE Modem or a particular service within that BWA CPE Modem.
4) 0x0000 – null address, addressed to no station.

The types of information elements which MUST be supported are defined below.

B.6.4.1.1.1 The Request IE

The Request IE provides an upstream interval in which requests MAY be made for bandwidth for upstream data transmission. The character of this IE changes depending on the class of Service ID. If broadcast, this is an invitation for BWA CPE Modems to contend for requests. BWA CPE Modems MUST choose a random mini-slot within this interval in which to transmit their requests, to reduce the possibility of collisions. If unicast, this is an invitation for a particular BWA CPE Modem to request bandwidth. Unicasts MAY be used as part of a class-of-service implementation (see below).

B.6.4.1.1.2 The Request/Data IE

The Request/Data IE provides an upstream interval in which requests for bandwidth or short data packets MAY be transmitted. This IE is distinguished from the Request IE in that:

- It provides a means by which allocation algorithms MAY provide for "immediate" data contention under light loads, and a means by which this opportunity can be withdrawn as network loading increases.
- Multicast Service IDs can be used to specify maximum data length, as well as allowed random starting points within the interval. For example, a particular multicast ID MAY specify a maximum of 64-byte data packets, with random starting points of every fourth slot.

A small number of well-known multicast Service IDs are defined in B.10. Others are available for vendor-specific algorithms.

Since data packets transmitted within this interval may collide, the BWA BTS Modem MUST acknowledge any that are successfully received. The data packet MUST indicate in the MAC Header that a data acknowledgement is desired (see Table B.6-12).

B.6.4.1.1.3 The Initial Maintenance IE

The Initial Maintenance IE provides an interval in which new stations may join the network. A long interval, equivalent to the maximum round-trip propagation delay plus the transmission time of the Ranging Request (RNG-REQ) message (see B.6.3.2.4), MUST be provided to allow new stations to perform initial ranging.

B.6.4.1.1.4 The Station Maintenance IE

The Station Maintenance IE provides an interval in which stations are expected to perform some aspect of routine network maintenance, such as ranging or power adjustment. The BWA BTS Modem MAY request that a particular BWA CPE Modem perform some task related to network maintenance, such as periodic transmit power adjustment. In this case, the Station Maintenance IE is unicast to provide upstream bandwidth in which to perform this task.

B.6.4.1.1.5 Short and Long Data Grant IEs

The Data Grant IE provides an opportunity for a BWA CPE Modem to transmit one or more upstream PDUs. These IEs MAY also be used, with a null slot range, to indicate that a request has been received and is pending. This IE is issued either in response to a request from a station, or because of an administrative policy providing some amount of bandwidth to a particular station (see class-of-service discussion below).

Short Data Grants are used with intervals less than or equal to the maximum burst size for this usage specified in the Upstream Channel Descriptor. If Short Data bursts are defined in the UCD, then all Long Data Grants MUST be for a larger number of mini-slots than the maximum for Short Data. The distinction between Long and Short Data Grants may be exploited in physical-layer forward-error-correction coding; otherwise, it is not meaningful to the bandwidth allocation process.

If this IE is a null-interval acknowledgement, it MUST follow all non-null-interval IEs. This allows BWA CPE modems to process all actual interval allocations first, before scanning the Map for request acknowledgements and data acknowledgements.

B.6.4.1.1.6 Data Acknowledge IE

The Data Acknowledge IE acknowledges that a data PDU was received. The BWA CPE Modem MUST have requested this acknowledgement within the data PDU (normally this would be done for PDUs transmitted within a contention interval in order to detect collisions).

This IE MUST follow all non-null-interval IEs. This allows BWA CPE modems to process all actual interval allocations first, before scanning the Map for request acknowledgements and data acknowledgements.

B.6.4.1.1.7 Expansion IE

The Expansion IE provides for extensibility, if more than 16 code points or 32 bits are needed for future IEs.

B.6.4.1.1.8 Null IE

A Null IE terminates all actual allocations in the IE list. It is used to infer a length for the last interval. All data acknowledgements and all null data grants follow the Null IE.

B.6.4.1.2 Requests

Only one type of upstream request is inherent to the allocation protocol: a request for upstream bandwidth. This request MAY be transmitted any time that either a request or a data PDU is allowed from the particular station. It MAY be transmitted during an interval described by any of:

- A Request IE.
- A Request/Data IE.
- A Data Grant IE.

In addition, it MAY be piggybacked[7] on a data transmission. The request includes:

- The Service ID making the request.
- The number of mini-slots or ATM cells requested.

The number of mini-slots requested MUST be the total number that are desired by the BWA CPE Modem at the time of the request, subject to administrative limits[8]. The BWA CPE Modem MUST request a number of mini-slots corresponding to one or more complete packets. A non-concatenating BWA CPE Modem MUST request only the necessary mini-slots for one MAC frame per request. If, for whatever reason, a previous request has not been satisfied when the BWA CPE Modem is making a new request, it MUST include the number of slots from the old request in the new total. Note that only one request at a time (per Service ID) will be outstanding. Because the BWA BTS Modem MUST continue to issue null grants for as long as a request is unsatisfied, the BWA CPE Modem is able to unambiguously determine when its request is still pending.

Administrative limits MAY be assigned, either globally or per Service ID, on the number of mini-slots that MAY be requested at once. The global limit is configured as the maximum transmission burst size.

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[7] When piggybacked, these values are carried in the Extended Header (clause B.6.2.6, EH_TYPE = 1).

[8] The BWA CPE is limited by the maximum transmit burst for the service class, as defined in Annex B.

B.6.4.2 Map Transmission and Timing

The allocation map MUST be transmitted in time to propagate across the physical BWA and be received and handled by the receiving BWA CPE Modems. As such, it MAY be transmitted considerably earlier than its effective time. The components of the delay are:

- Worst-case round-trip propagation delay – may be network-specific, but on the order of hundreds of microseconds.
- Queuing delays within the BWA BTS Modem – implementation-specific.
- Processing delays within the BWA CPE Modems – MUST allow a minimum processing time by each BWA CPE Modem as specified in Annex B (BWA CPE Modem MAP Processing Time).
- PMD-layer FEC interleaving.

Within these constraints, vendors MAY wish to minimise this delay so as to minimise latency of access to the upstream channel.

The number of mini-slots described MAY vary from map to map. At minimum, a map MAY describe a single mini-slot. This would be wasteful in both downstream bandwidth and in processing time within the BWA CPE Modems. At maximum, a map MAY stretch to tens of milliseconds. Such a map would provide poor upstream latency. Allocation algorithms MAY vary the size of the maps over time to provide a balance of network utilisation and latency under varying traffic loads.

At minimum, a map MUST contain two Information Elements: one to describe an interval and a null IE to terminate the list. At a maximum, a map MUST be bounded by a limit of 240 information elements. Maps are also bounded in that they MUST NOT describe more than 4096 mini-slots into the future. The latter limit is intended to bound the number of future mini-slots that each BWA CPE Modem is required to track. Even though several maps may be outstanding, the sum of the number of mini-slots they describe MUST NOT exceed 4096.

The set of all maps, taken together, MUST describe every mini-slot in the upstream channel. If a BWA CPE Modem fails to receive a map describing a particular interval, it MUST NOT transmit during that interval.

Multiple maps MAY be outstanding at once.

B.6.4.3 Protocol example

This clause illustrates the interchange between the BWA CPE Modem and the BWA BTS Modem when the BWA CPE Modem has data to transmit (Figure B.6-32). Suppose a given BWA CPE Modem has a data PDU available for transmission.

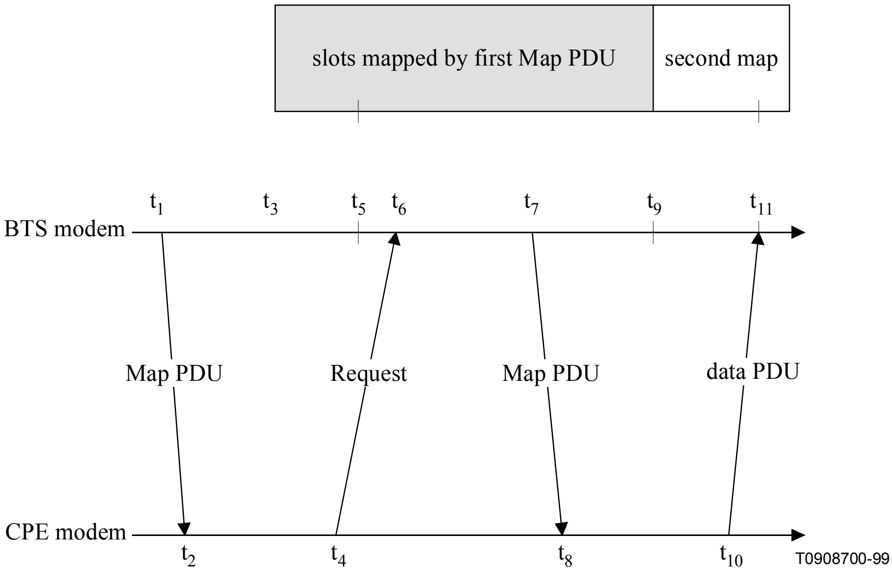


Figure B.6-32/J.116 – Protocol example

Description

1) At time t_1, the BWA BTS Modem transmits a map whose effective starting time is t_3. Within this map is a Request IE which will start at t_5. The difference between t_1 and t_3 is needed to allow for:
   - downstream propagation delay (including FEC interleaving) to allow all BWA CPE Modems to receive the Map;
   - processing time at the BWA CPE Modem (allows the BWA CPE Modems to parse the Map and translate it into transmission opportunities);
   - upstream propagation delay (to allow the BWA CPE Modem's transmission of the first upstream data to begin in time to arrive at the BWA BTS Modem at time t_3).

2) At t_2, the BWA CPE Modem receives this map and scans it for request opportunities. In order to minimise request collisions, it calculates t_6 as a random offset from t_5 within the interval described by the Request IE (see B.6.4.4, also the multicast SID definitions in B.10.2).

3) At t_4, the BWA CPE Modem transmits a request for as many mini-slots as needed to accommodate the PDU. Time t_4 is chosen based on the ranging offset (see B.6.3.2.5) so that the request will arrive at the BWA BTS Modem at t_6.

4) At t_6, the BWA BTS Modem receives the request and schedules it for service in the next map. (The choice of which requests to grant will vary with the class of service requested, any competing requests, and the algorithm used by the BWA BTS Modem.)

5) At t_7, the BWA BTS Modem transmits a map whose effective starting time is t_9. Within this map, a data grant for the BWA CPE Modem will start at t_{11}.

6) At t_8, the BWA CPE Modem receives the map and scans for its data grant.

7) At t_{10}, the BWA CPE Modem transmits its data PDU so that it will arrive at the BWA BTS Modem at t_{11}. Time t- is calculated from the ranging offset as in step 3).

Steps 1) and 2) need not contribute to access latency if BWA CPE Modems routinely maintain a list of request opportunities.

At Step 3), the request may collide with requests from other BWA CPE Modems and be lost. The BWA BTS Modem does not directly detect the collision. The BWA CPE Modem determines that a collision (or other reception failure) occurred when the next map fails to include acknowledgement of the request. The BWA CPE Modem MUST then perform a back-off algorithm and retry.

At Step 4), the BWA BTS Modem scheduler MAY fail to accommodate the request within the next map. If so, it MUST reply with a zero-length grant in that map. It MUST continue to report this zero-length grant in all succeeding maps until the request can be granted. This MUST signal to the BWA CPE Modem that the request is still pending. So long as the BWA CPE Modem is receiving a zero-length grant, it MUST NOT issue new requests for that service queue.

B.6.4.4 Contention Resolution

The BWA BTS Modem controls assignments on the upstream channel through the MAP and determines which mini-slots are subject to collisions. The BWA BTS Modem MAY allow collisions on either Requests or Data PDUs.

The mandatory method of contention resolution which MUST be supported is based on a truncated binary exponential back-off, with the initial back-off window and the maximum back-off window controlled by the BWA BTS Modem. The values are specified as part of the Bandwidth Allocation Map (MAP) MAC message and represent a power-of-two value. For example, a value of 4 indicates a window between 0 and 15; a value of 10 indicates a window between 0 and 1023.

When a BWA CPE Modem has information to send and wants to enter the contention resolution process, it sets its internal back-off window equal to the initial back-off window defined in the MAP currently in effect.

The BWA CPE Modem MUST randomly select a number within its back-off window. This random value indicates the number of contention transmit opportunities which the BWA CPE Modem MUST defer before transmitting. A BWA CPE Modem MUST only consider contention transmit opportunities for which this transmission would have been eligible. These are defined by either Request IEs or Request/Data IEs in the MAP.

NOTE 1 – Each IE can represent multiple transmission opportunities.

As an example, consider a BWA CPE Modem whose initial back-off window is 0 to 15 and it randomly selects the number 11. The BWA CPE Modem must defer a total of 11 contention transmission opportunities. If the first available Request IE is for 6 requests, the BWA CPE Modem does not use this and has 5 more opportunities to defer. If the next Request IE is for 2 requests, the BWA CPE Modem has 3 more to defer. If the third Request IE is for 8 requests, the BWA CPE Modem transmits on the fourth request, after deferring for 3 more opportunities.

After a contention transmission, the BWA CPE Modem waits for a Data Grant (Data Grant Pending) or Acknowledgement in a subsequent MAP. Once either is received, the contention resolution is complete. The BWA CPE Modem determines that the contention transmission was lost when it finds a MAP without a Data Grant (Data Grant Pending) or Acknowledgement for it and with an Ack time more recent than the time of transmission. The BWA CPE Modem MUST now increase its back-off window by a factor of two, as long as it is less than the maximum back-off window. The BWA CPE Modem MUST randomly select a number within its new back-off window and repeat the deferring process described above.

This retry process continues until the maximum number of retries (16) has been reached, at which time the PDU MUST be discarded.

NOTE 2 – The maximum number of retries is independent of the initial and maximum back-off windows that are defined by the BWA BTS Modem.

If the BWA CPE Modem receives a unicast Request or Data Grant at any time while deferring for this SID, it MUST stop the contention resolution process and use the explicit transmit opportunity.

The BWA BTS Modem has much flexibility in controlling the contention resolution. At one extreme, the BWA BTS Modem MAY choose to set up the initial and maximum back-off windows to emulate an Ethernet-style back-off with its associated simplicity and distributed nature, but also its fairness and efficiency issues. This would be done by setting initial = 0 and max = 10 in the Upstream Channel Descriptor. At the other end, the BWA BTS Modem MAY make the initial and maximum back-off windows identical and frequently update these values in the MAP so all BWA CPE modems are using the same, and hopefully optimal, back-off window.

B.6.4.5 BWA CPE Modem Behaviour

The following rules govern the response a BWA CPE Modem may make when processing maps:

1) A BWA CPE Modem MUST first use any Grants assigned to it. Next, the BWA CPE Modem MUST use any unicast REQ for it. Finally, the BWA CPE Modem MUST use the next available broadcast/multicast REQ or REQ/Data IEs for which it is eligible.
2) Only one Request may be outstanding at a time for a particular Service ID.
3) If a BWA CPE Modem has a Request pending, it MUST NOT use intervening contention intervals for that Service ID.

B.6.4.6 Support for Multiple Channels

Vendors MAY choose to offer various combinations of upstream and downstream channels within one MAC service access point. The upstream bandwidth allocation protocol allows for multiple upstream channels to be managed via one or many downstream channels.

If multiple upstream channels are associated with a single downstream channel, then the BWA BTS Modem MUST send one allocation map per upstream channel. The map's channel identifier, taken with the Upstream Channel Descriptor Message (see B.6.3.2.2), MUST specify to which channel each map applies. There is no requirement that the maps be synchronised across channels.

If multiple downstream channels are associated with a single upstream channel, the BWA BTS Modem MUST ensure that the allocation map reaches all BWA CPE Modems. That is, if some BWA CPE Modems are attached to a particular downstream channel, then the map MUST be transmitted on that channel. This MAY necessitate that multiple copies of the same map be transmitted. The slot reference in the map header MUST always relate to the SYNC reference on the downstream channel on which it is transmitted.

If multiple downstream channels are associated with multiple upstream channels, the BWA BTS Modem MAY need to transmit multiple copies of multiple maps to ensure both that all upstream channels are mapped and that all BWA CPE Modems have received their needed maps.

B.6.4.7 Classes of Service

This specification does not provide explicit classes of service, but provides the means for vendors to provide a variety of types of service.

This clause illustrates how the available mechanisms can be used to provide support for the service classes defined in IETF RFC 1633 "Integrated Services in the Internet Architecture: An Overview".

IETF RFC 1633 divides applications into elastic applications which will always wait for data to arrive and inelastic applications in which the data must arrive within a certain time to be useful.

Within the inelastic category further subdivisions can be defined:

- delay-intolerant – the data must arrive within a perfectly reliable upper bound on delay;
- delay-tolerant – the data must arrive within a fairly reliable but not perfectly reliable delay bound.

Within the elastic category the following application types can be distinguished:

- interactive burst;
- interactive bulk.

The service model should be able to support both types of inelastic application and to allow for lower delays for interactive elastic applications than for bulk elastic applications.

Inelastic Delay-Intolerant – The BWA BTS Modem provides a Data Grant of fixed size to a configured Service ID once every N mini-slots. This Service ID MAY be assigned to all traffic for a BWA CPE modem, or it MAY only be used for this particular service within the BWA CPE modem.

Inelastic Delay-Tolerant – The BWA BTS Modem periodically provides a unicast Request IE to a configured Service ID. It then grants the request based on the negotiated delay variation, bandwidth, and other considerations. The BWA CPE Modem has guaranteed access in which to make requests, and the BWA BTS Modem's scheduling algorithm provides the negotiated service. As an alternative, the minimum data rate of the service negotiation MAY be provided in the same way that inelastic delay-intolerant traffic is handled.

Elastic Application Support – Is provided by a contention/FIFO service strategy, in which BWA CPE Modems contend for request slots, and the BWA BTS Modem services requests as they arrive. Service priorities can allow differential delays between interactive and bulk applications.

B.6.4.7.1 Resource-Sharing

In order to support multiple end systems sharing the same upstream and downstream links, it is necessary to provide resource-sharing mechanisms for the link bandwidth. The following are some examples of this:

Link-usage feedback – Is provided implicitly by contention and by the BWA BTS Modem's scheduling algorithm, so no explicit congestion notifications are needed.

Guaranteed Minimum Bit Rate – Can be provided in much the same manner as inelastic delay-tolerant application support.

Guaranteed Maximum Bit Rate – MAY be provided by a number of implementation mechanisms, including the BWA BTS Modem's allocation algorithm and throttling within the BWA CPE Modem.

Service Priorities MUST be implemented by applying different service criteria to different Service IDs. It is anticipated that a particular BWA CPE Modem MAY have several Service IDs, each corresponding to a particular service class. The particular services offered MAY vary from vendor to vendor.

Contention that is limited to a service class MAY be accomplished with multicast Request IEs and Request/Data IEs. Creation of such multicast groups is vendor-specific.

B.6.5 Timing and Synchronisation

One of the major challenges in designing a MAC protocol for a BWA network is compensating for the large delays involved. These delays are an order of magnitude larger than the transmission burst time in the upstream. To compensate for these delays, the BWA CPE modem MUST be able to time its transmissions precisely to arrive at the BWA BTS Modem at the start of the assigned mini-slot.

To accomplish this, two pieces of information are needed by each BWA CPE modem:

- a global timing reference sent downstream from the BWA BTS Modem to all BWA CPE modems;
- a timing offset, calculated during a ranging process, for each BWA CPE modem.

B.6.5.1 Global Timing Reference

The BWA BTS Modem MUST create a global timing reference by transmitting the Time Synchronisation (SYNC) MAC management message downstream at precise times. The message contains a timestamp that exactly identifies when the BWA BTS Modem transmitted the message. BWA CPE modems MUST then compare the actual time the message was received with the timestamp and adjust their local clock references accordingly.

The SYNC message MUST be transmitted on a periodic basis called the MAC SYNC Interval (MSI). The BWA BTS Modem MUST transmit one SYNC message within each MSI. The BWA BTS Modem determines when to send the SYNC message based on the requirements of this and other downstream traffic. The maximum separation between any SYNC messages is therefore 2 MSI periods.

The Transmission Convergence sublayer must operate closely with the MAC sublayer to provide an accurate timestamp for the SYNC message. As mentioned in the Ranging subclause below (clause B.6.5.3), the model assumes that the timing delays through the remainder of the PHY layer MUST be relatively constant. Any variation in the PHY delays MUST be accounted for in the guard time of the PHY overhead.

It is intended that the MAC Sync Interval be on the order of tens of milliseconds. This imposes very little downstream overhead while letting BWA CPE modems acquire their global timing synchronisation quickly.

B.6.5.2 BWA CPE Modem Channel Acquisition

Any BWA CPE modem MUST NOT use the upstream channel until it has successfully synchronised to the downstream.

First, the BWA CPE modem MUST establish PMD sublayer synchronisation. This implies that it has locked onto the correct frequency, equalised the downstream channel, recovered any PMD sublayer framing and the FEC is operational (refer to clause B.7.2.1). At this point, a valid bit stream is being sent to the transmission convergence sublayer. The transmission convergence sublayer performs its own synchronisation (see clause B.5). On detecting the well-known BWA PID, along with a payload unit start indicator per ITU-T H.222.0, it delivers the MAC frame to the MAC sublayer.

The MAC sublayer MUST now search for the Timing Synchronisation (SYNC) MAC management messages. The BWA CPE modem achieves MAC synchronisation once it has received at least two SYNC messages within the maximum SYNC interval and has verified that its clock tolerances are within specified limits.

A BWA CPE modem remains in "SYNC" as long as it continues to successfully receive the SYNC messages. If the Lost SYNC Interval (see clause B.11) has elapsed without a valid SYNC message, a BWA CPE modem MUST NOT use the upstream and MUST try to re-establish synchronisation again.

B.6.5.3 Ranging

Ranging is the process of acquiring the correct timing offset such that the BWA CPE modem's transmissions are aligned to the correct mini-slot boundary. The timing delays through the PHY layer MUST be relatively constant. Any variation in the PHY delays MUST be accounted for in the guard time of the upstream PMD overhead.

First, a BWA CPE modem MUST synchronise to the downstream and learn the upstream channel characteristics through the Upstream Channel Descriptor MAC management message. At this point, the BWA CPE modem MUST scan the Bandwidth Allocation MAP message to find a Station Maintenance region assigned to initialising BWA CPE Modems. Refer to subclause B.6.4.1.1.4. The BWA BTS Modem MUST make a Station Maintenance region large enough to account for the variation in delays between any two BWA CPE Modems.

The BWA CPE modem MUST put together a Ranging Request message to be sent in the Station Maintenance region. The SID field MUST be set to the non-initialised BWA CPE Modem value (zero).

Ranging adjusts each BWA CPE Modem's timing offset such that it appears to be located right next to the BWA BTS Modem. The BWA CPE Modem MUST set its initial timing offset to the amount of internal fixed delay equivalent to putting this BWA CPE Modem next to the BWA BTS Modem. This amount includes delays introduced through a particular implementation, and MUST include the downstream PHY interleaving latency.

When the Station Maintenance transmit opportunity occurs, the BWA CPE modem MUST send the Ranging Request message. Thus, the BWA CPE modem sends the message as if it was physically right at the BTS Modem.

Once the BWA BTS Modem has successfully received the Ranging Request message, it MUST return a Ranging Response message addressed to the individual BWA CPE modem. Within the Ranging Response message MUST be a temporary SID assigned to this BWA CPE modem until it has completed the registration process. The message MUST also contain information on RF power level adjustment and offset frequency adjustment as well as any timing offset corrections.

The BWA CPE modem MUST now wait for an individual Station Maintenance region assigned to its temporary SID. It MUST now transmit a Ranging Request message at this time using the temporary SID along with any power level and timing offset corrections.

The BWA BTS Modem MUST return another Ranging Response message to the BWA CPE modem with any additional fine tuning required. The ranging request/response steps MUST be repeated until the response contains a Ranging Successful notification. At this point, the BWA CPE modem MUST join normal data traffic in the upstream. See clause B.7 for complete details on the entire initialisation sequence. In particular, state machines and the applicability of retry counts and timer values for the ranging process are defined in clause B.6.2.4.

NOTE – The burst type to use for any transmission is defined by the Interval Usage Code (IUC). Each IUC is mapped to a burst type in the UCD message.

B.6.5.4 Timing Units and Relationships

The SYNC message conveys a time reference that is measured in 6.25-microsecond ticks. These units were chosen as the greatest-common-divisor of the upstream mini-slot time across various modulations and symbol rates. As this is decoupled from particular upstream channel characteristics, a single SYNC time reference may be used for all upstream channels associated with the downstream channel.

The bandwidth allocation MAP uses time units of "mini-slots". A mini-slot represents the byte-time needed for transmission of a fixed number of bytes. The size of the mini-slot, expressed as a multiple of the SYNC time reference, is carried in the Upstream Channel Descriptor. The example in Table B.6-18 relates mini-slots to the SYNC time ticks:

Table B.6-18/J.116 – Example Relating Mini-Slots to Time Ticks

Parameter	Example Value
Time tick	6.25 microseconds
Mini-slots/second	40 000
Microseconds/mini-slot	25
Ticks/mini-slot	4

The reader is encouraged to try other symbol rates and modulations. Note that the symbols/byte is a characteristic of an individual burst transmission, not of the channel.

A "mini-slot" is the unit of granularity for upstream transmission opportunities. There is no implication that any PDU can actually be transmitted in a single mini-slot.

The MAP counts mini-slots in a 32-bit counter that counts to (2^{32-1}) and then wraps back to zero. The least-significant bits of the mini-slot counter MUST match the most-significant bits of the SYNC counter. That is, mini-slot N begins at time reference (N * T), where T is the UCD multiplier (T is always a power of 2).

Note that the constraint that the UCD multiplier be a power of two has the consequence that the number of bytes per mini-slot must also be a power of two.

B.6.6 Data Link Encryption Support

The procedures to support data link encryption are defined in MCNS2 and MCNS8[1]. The interaction between the MAC layer and the security system is limited to the items defined below.

B.6.6.1 MAC Messages

MAC management messages (clause B.6.3) MUST NOT be encrypted.

B.6.6.2 Framing

Security information is carried as payload data to the MAC and is essentially transparent. A frame carrying an encrypted payload MUST be constructed as shown in Figure B.6-33.

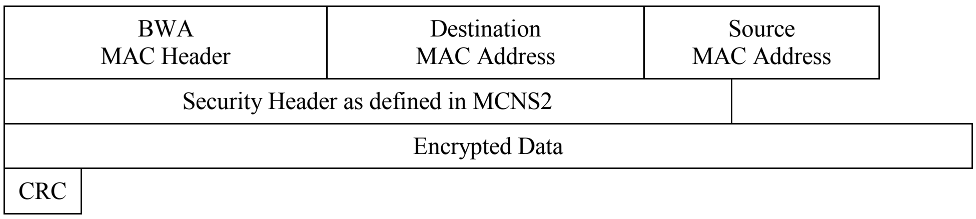


Figure B.6-33/J.116 – Security Framing

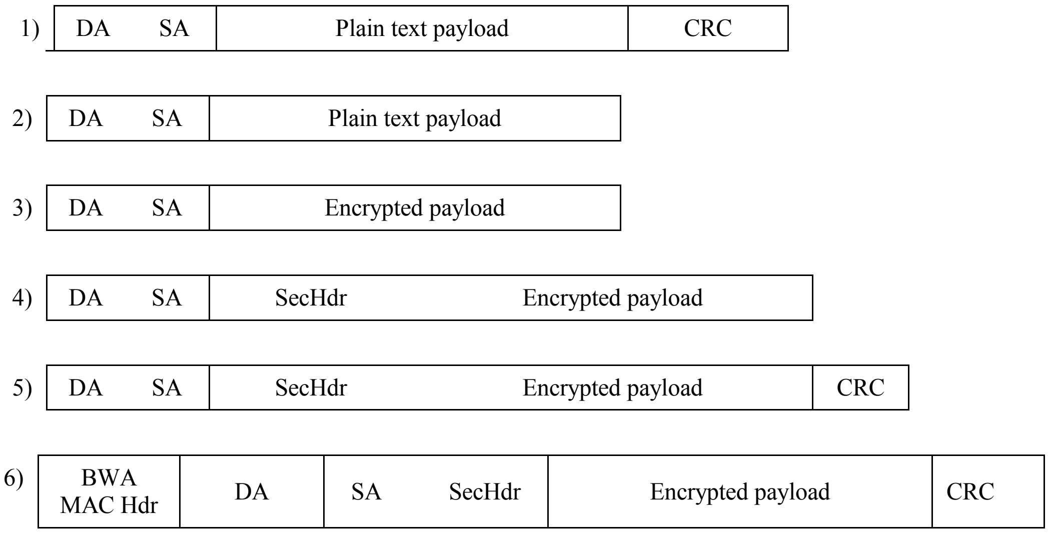
The following rules MUST be followed when the encrypted frame is constructed:

- The DLE flag in the FC field of the MAC Header MUST be set.
- The security header MUST follow the MAC source address, and MUST precede the type/length field.
- The security header will be a multiple of 4 bytes to optimise alignment.
- The message payload must be encrypted and decrypted using the mechanism defined in the following steps.

This example is defined for a frame received by a BWA CPE Modem at the CPE Modem to CPI interface and transferred over the BWA network to the BWA BTS Modem and forwarded via an Ethernet based NSI. For frames travelling in the NSI-to-CPE Modem to CPI interface direction, the roles of BWA CPE Modem and BWA BTS Modem are reversed.

B.6.6.2.1 CPE Modem to CPI interface to RF

Refer to Figure B.6-34.

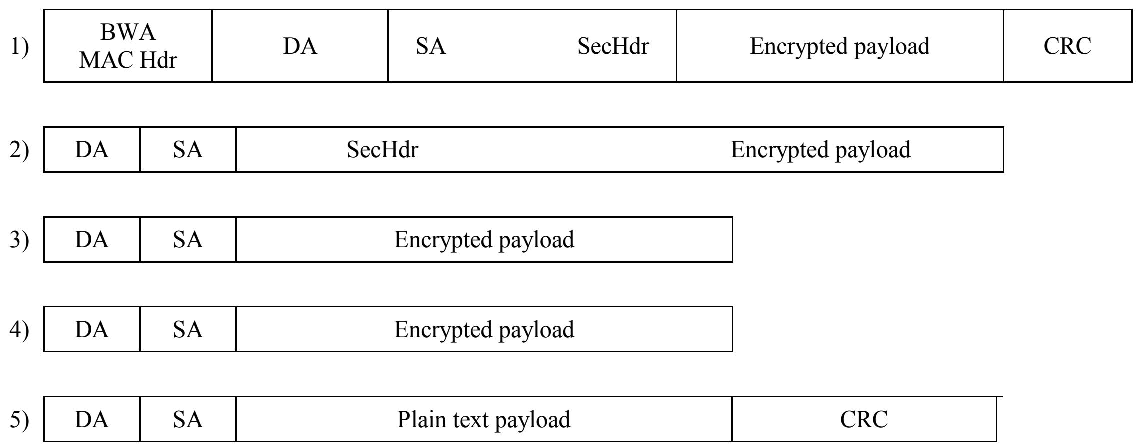


1) BWA CPE modem receives frame for Ethernet.
2) Check and discard Ethernet CRC.
3) Encrypt payload.
4) Add security header.
5) Calculate new CRC over DA, SA, security header and encrypted payload.
6) Add BWA MAC header and forward on to the RF transmitter.

Figure B.6-34/J.116 – Example of Security Framing at the BWA CPE modem

B.6.6.2.2 RF to BWA BTS-NSI

Refer to Figure B.6-35.



1) Check and discard MAC header.
2) Check and discard CRC.
3) Remove security header.
4) Decrypt payload.
5) Recalculate CRC and forward frame to BTS-NSI.

Figure B.6-35/J.116 – Example of Security Framing at the BWA BTS

B.7 BWA CPE modem – BWA BTS Modem Interaction

This clause covers key requirements for interaction between the BWA CPE modem and BWA BTS Modem. The interaction can be broken down into five basic categories: modem initialisation, authentication, configuration, authorisation and signalling.

B.7.1 BWA BTS Modem Initialisation

The mechanism utilised for BWA BTS Modem initialisation (local terminal, file download, SNMP, etc.) is described in MCNS5[1]. It MUST meet the following criteria for system interoperability:

- the BWA BTS Modem MUST be able to reboot and operate in a stand-alone mode using configuration data retained in non-volatile storage;
- if valid parameters are not available from non-volatile storage or via another mechanism such as the Spectrum Management System (see SMS), the BWA BTS Modem MUST not generate any downstream messages (including SYNC). This will prevent BWA CPE Modems from transmitting;
- the BWA BTS Modem MUST provide the information defined in clause B.6 to BWA CPE Modems for each upstream channel.

B.7.2 BWA CPE modem Initialisation

The procedure for initialisation of a BWA CPE modem MUST be as shown in Figure B.7-1. This figure shows the overall flow between the stages of initialisation in a BWA CPE Modem. This shows no error paths, and is simply to provide an overview of the process. The more detailed finite state machine representations of the individual sections (including error paths) are shown in the subsequent figures. Timeout values are defined in clause B.11.

The procedure can be divided into the following phases:

- scan for downstream channel and establish synchronisation with the BWA BTS Modem;
- obtain transmit parameters (from UCD message);
- perform ranging;
- establish IP connectivity;
- establish time of day;
- establish security association;
- transfer operational parameters.

Each BWA CPE Modem contains the following information when shipped from the manufacturer:

- a unique IEEE 802 48-bit MAC address which is assigned during the manufacturing process. This is used to identify the modem to the various provisioning servers during initialisation;
- security information as defined in MCNS2 and MCNS8[1] (e.g. X.509 certificate) used to authenticate the BWA CPE Modem to the security server and authenticate the responses from the security and provisioning servers.

The SDL (Specification and Description Language) notation used in the following figures is shown in Figure B.7-2 (refer to ITU-T Z.100).

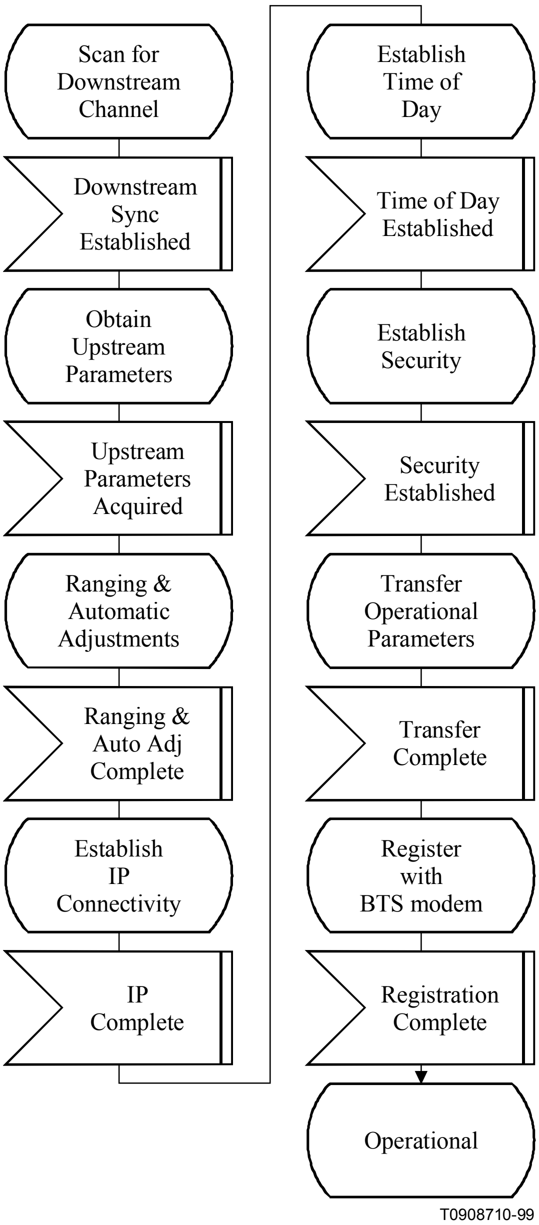


Figure B.7-1/J.116 – BWA CPE Modem Initialisation Overview

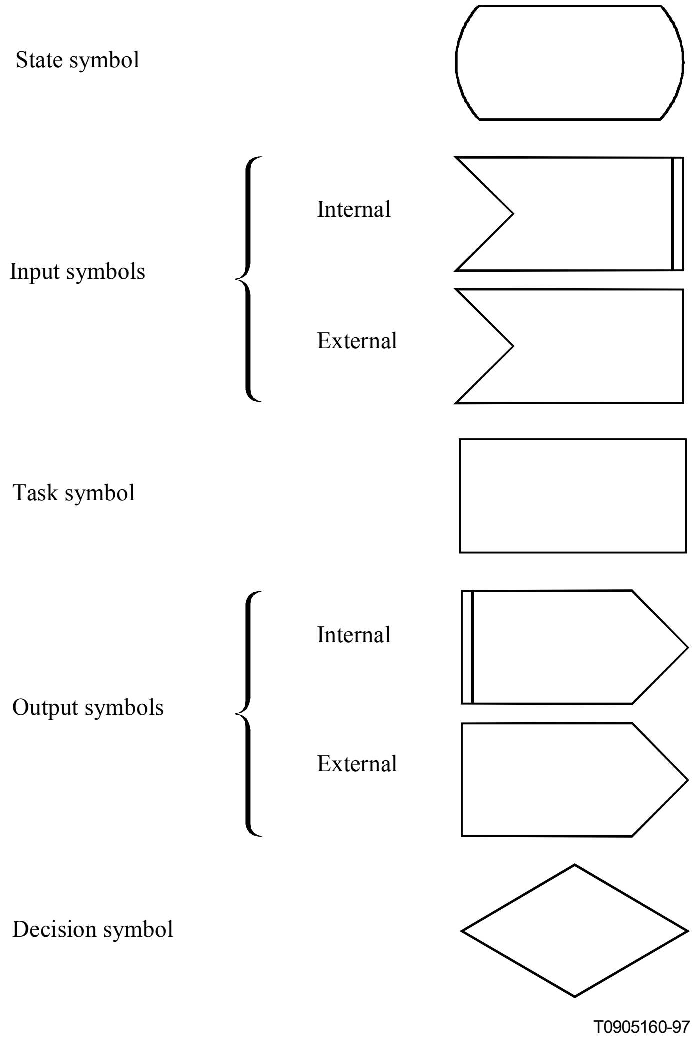


Figure B.7-2/J.116 – SDL Notation

B.7.2.1 Scanning and Synchronisation to Downstream

On initialisation or after signal loss, the BWA CPE modem MUST acquire a downstream channel. The BWA CPE Modem MUST have non-volatile storage in which the last operational parameters are stored and MUST first try to re-acquire this downstream channel. If this fails, it MUST begin to continuously scan the RF channels of the downstream frequency band of operation until it finds a valid downstream signal.

A downstream signal is considered to be valid when the modem has achieved the following steps:

- synchronisation of the QAM symbol timing;
- synchronisation of the FEC framing;
- synchronisation of the MPEG packetisation;
- recognition of SYNC downstream MAC messages.

While scanning, it is desirable to give an indication to the user that the BWA CPE Modem is doing so.

B.7.2.2 Obtain Upstream Parameters

Refer to Figure B.7-3 after synchronisation, the BWA CPE Modem MUST wait for an upstream channel descriptor message (UCD) from the BWA BTS Modem in order to retrieve transmission parameters from the data stream. These messages are transmitted periodically from the BWA BTS Modem for all available upstream channels and are addressed to the MAC broadcast address. The BWA CPE Modem MUST determine whether it can use the upstream channel from the channel description parameters. If the channel is not suitable, then the BWA CPE Modem MUST wait for a channel description message for a channel which it can use. If no channel can be found after a suitable timeout period, then the BWA CPE Modem MUST continue scanning to find another downstream channel.

When the BWA CPE modem finds an upstream channel with acceptable transmission parameters, it MUST extract the parameters for this upstream from the UCD. It then MUST wait for the next SYNC message[9] and extract the upstream mini-slot timestamp from this message. The BWA CPE Modem then MUST wait for a bandwidth allocation map for the selected channel. It MAY then begin transmitting upstream in accordance with the MAC operation and the bandwidth allocation mechanism.

It is desirable to give an indication to the user that the BWA CPE Modem has finished searching and has detected a valid downstream signal and upstream channel.

[9] Alternatively, since the SYNC message applies to all upstream channels, the BWA CPE Modem may have already acquired a time reference from previous SYNC messages. If so, it need not wait for a new SYNC.

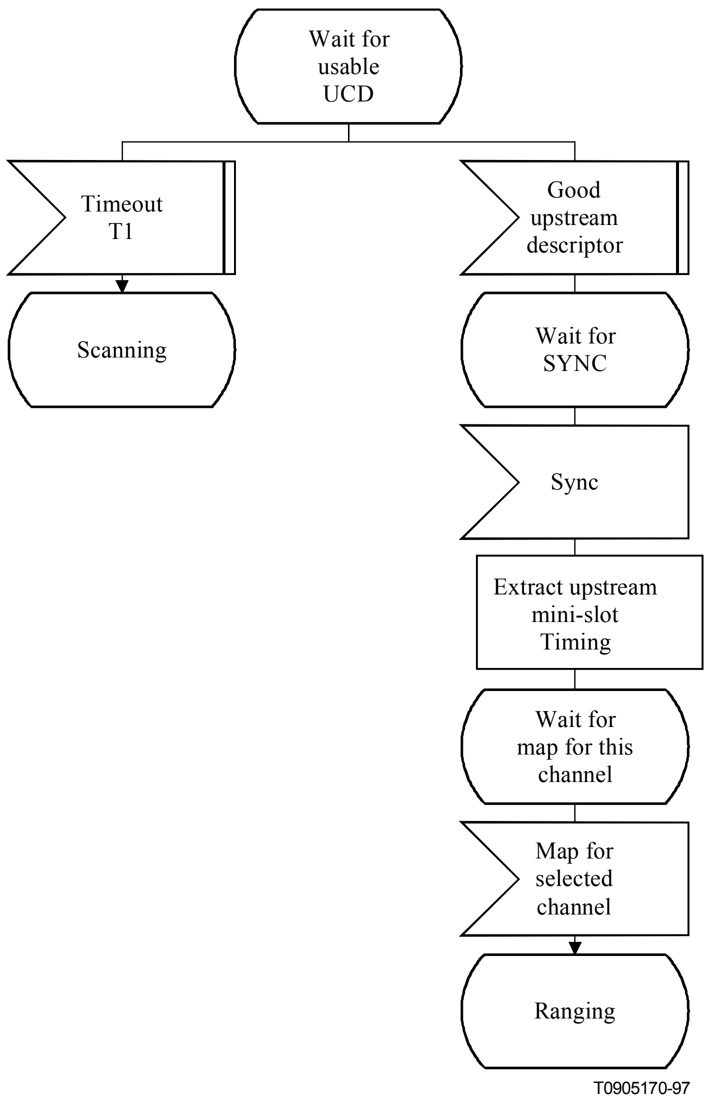


Figure B.7-3/J.116 – Obtaining Upstream Parameters

B.7.2.3 Message flows during scanning and upstream parameter acquisition

The BWA BTS Modem MUST generate SYNC and UCD messages on the downstream at periodic intervals within the ranges defined in clause B.6. These messages are addressed to all BWA CPE Modems. Refer to Figure B.7-4.

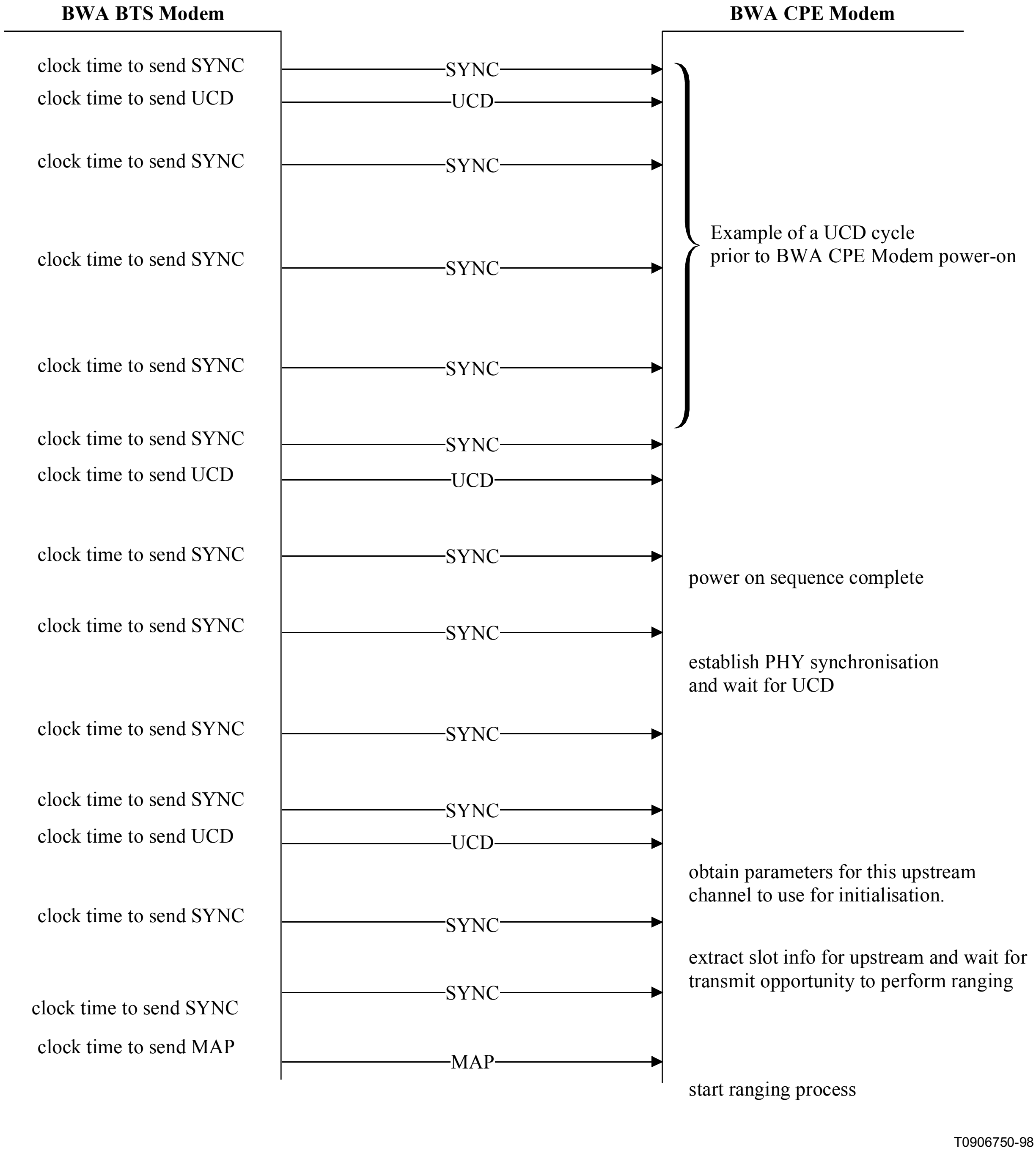


Figure B.7-4/J.116 – Message flows during scanning and upstream parameter acquisition

B.7.2.4 Ranging and automatic adjustments

The ranging and adjustment process is fully defined in clause B.6 and in the following subclauses. The message sequence chart and the finite state machines on the following pages define the ranging and adjustment process which MUST be followed by compliant BWA CPE Modems and BWA BTS Modems. Refer to Figures B.7-5 through B.7-8.

NOTE 1 – MAPs are transmitted as described in clause B.6.

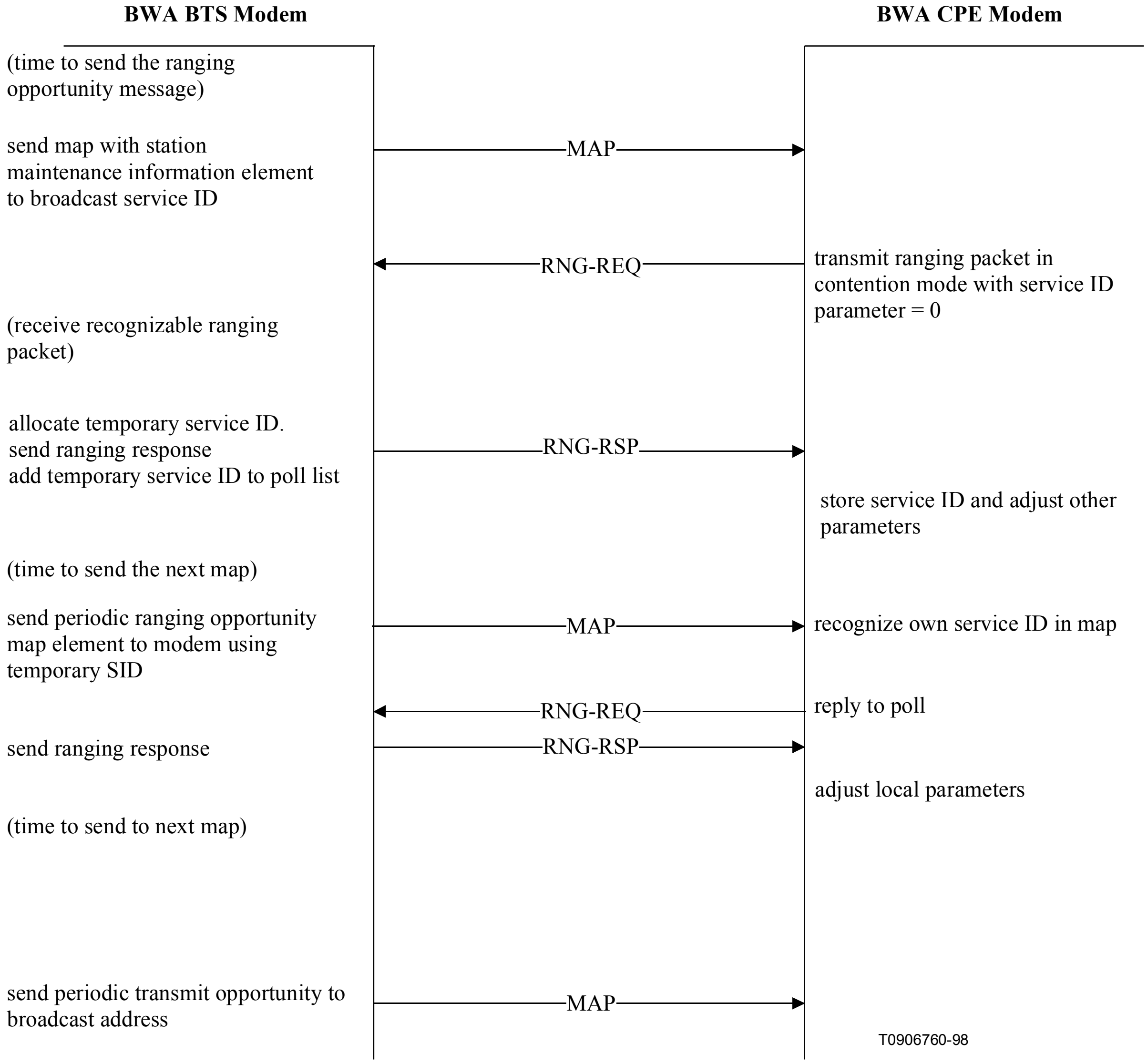
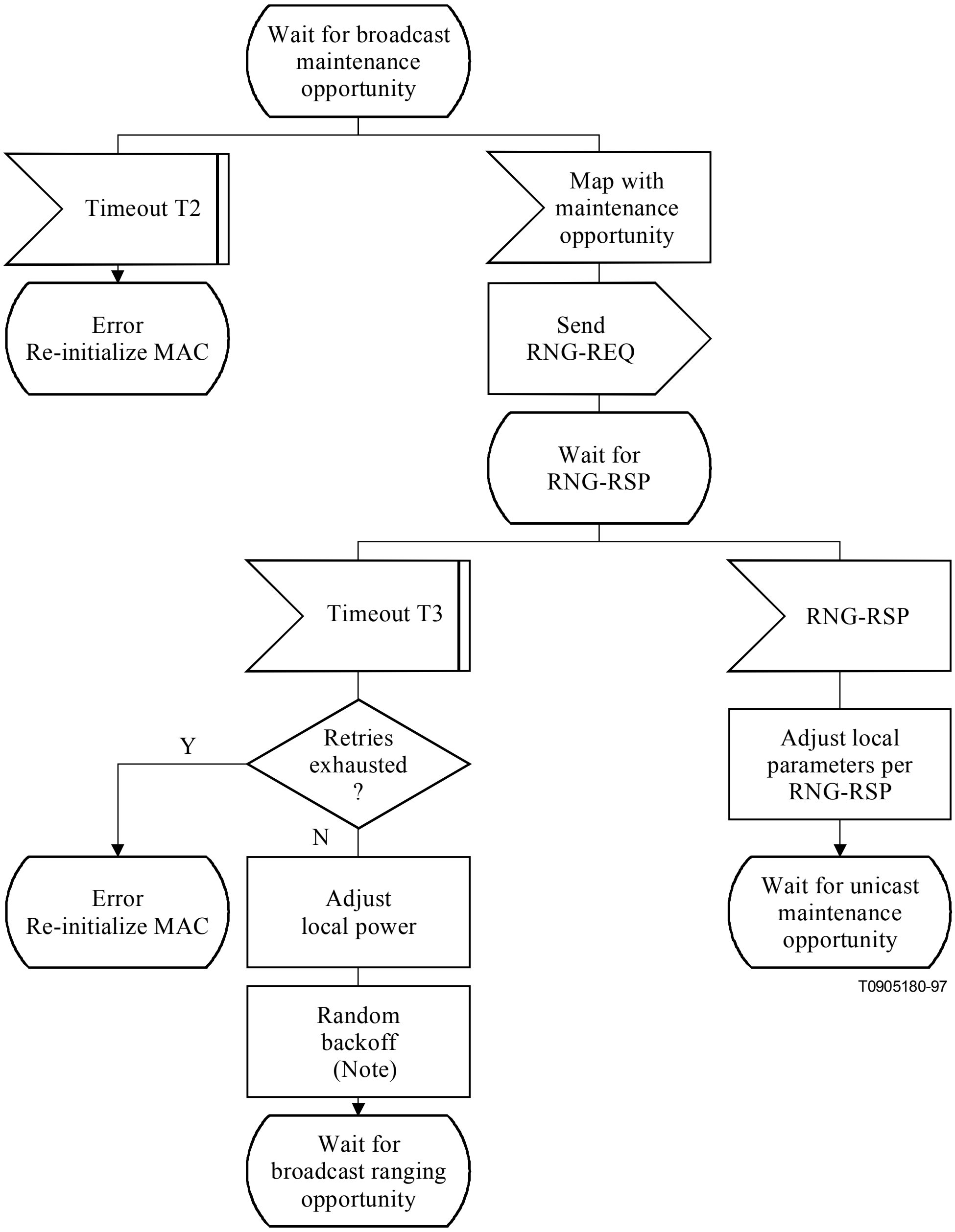


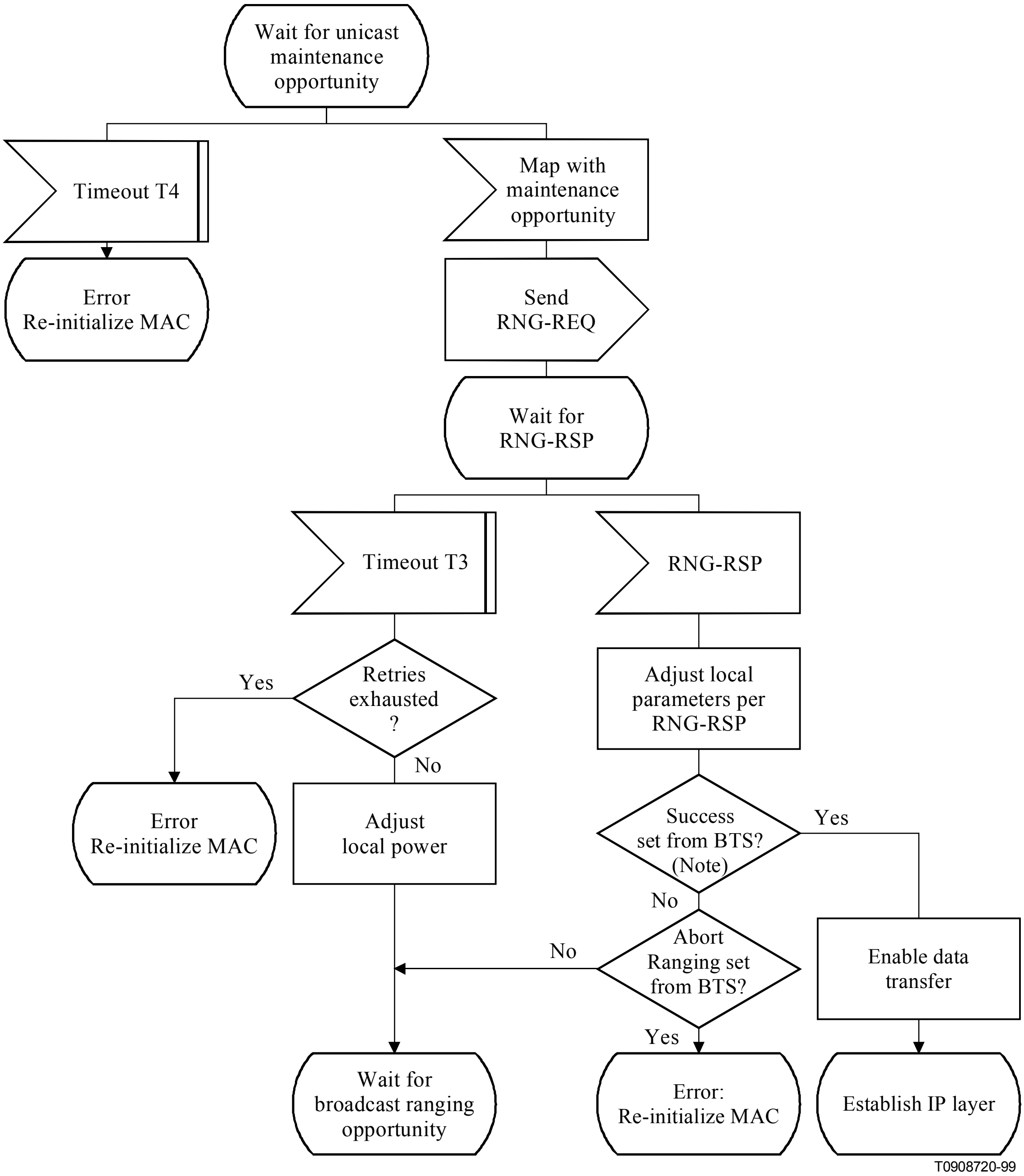
Figure B.7-5/J.116 – Ranging and Automatic Adjustments Procedure

NOTE 2 – The BWA BTS Modem MUST allow the BWA CPE Modem sufficient time to have processed the previous RNG-RSP (i.e. to modify the transmitter parameters) before sending the BWA CPE Modem a specific ranging opportunity. This is defined as BWA CPE Modem Ranging Response Time in clause B.11.



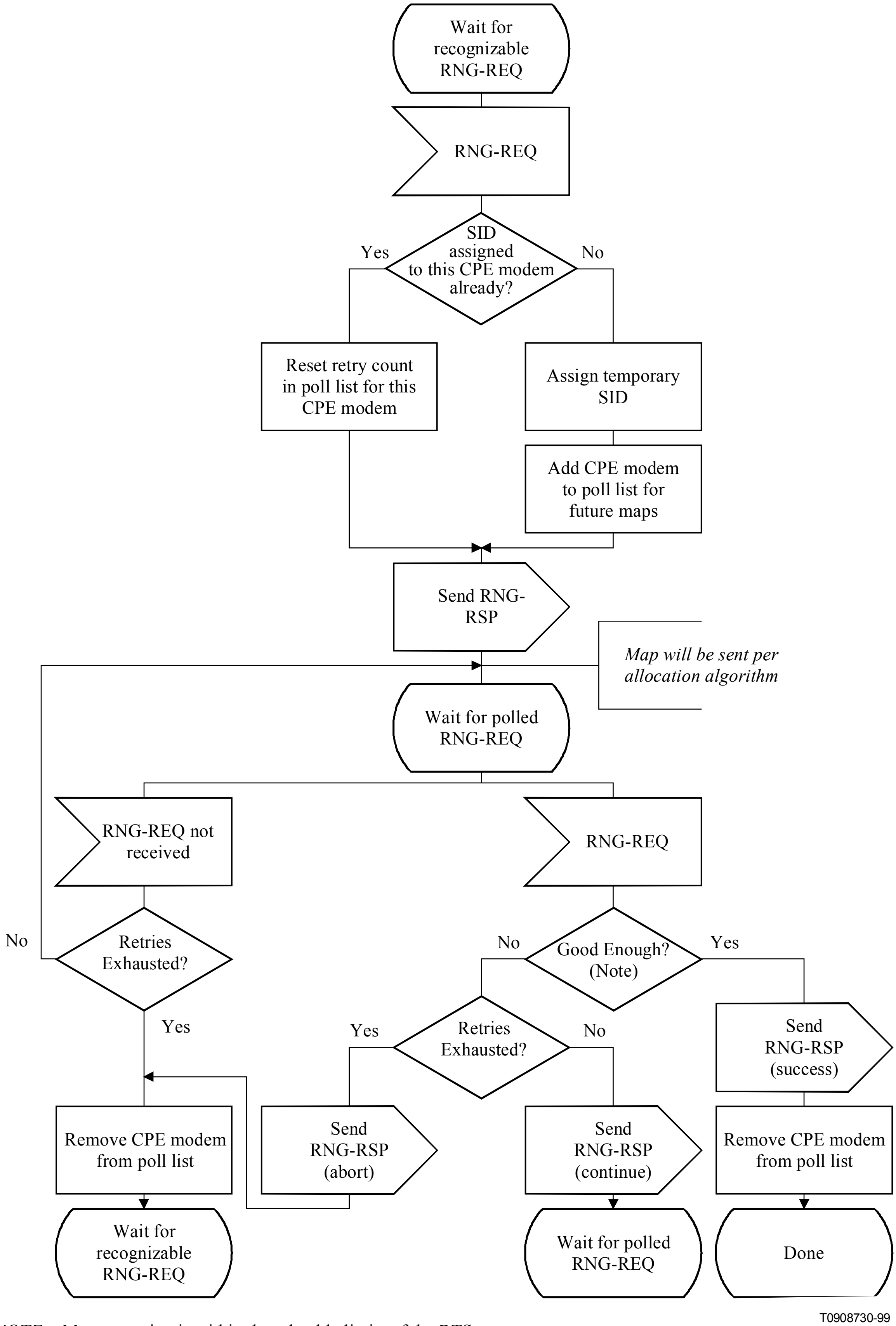
NOTE – Timeout T3 may occur because the RNG-REQs from multiple modems collided. To avoid these modems repeating the loop in lockstep, a random backoff is required. This is a backoff over the ranging window specified in the UCD.

Figure B.7-6/J.116 – Initial Ranging – BWA CPE Modem



NOTE – Ranging Request is within the tolerance of the BTS.

Figure B.7-7/J.116 – Initial Ranging – BWA CPE Modem



NOTE – Means ranging is within the tolerable limits of the BTS.

Figure B.7-8/J.116 – Initial Ranging – BWA BTS modem

Ranging parameter adjustment

Adjustment of local parameters (e.g. transmit power) in a BWA CPE Modem as a result of the receipt (or non-receipt) of an RNG-RSP is considered to be implementation-dependent with the following restrictions (refer to clause B.6.2.7):

- all parameters MUST be within the approved range at all times;
- power adjustment MUST start from the minimum value unless a valid power is available from non-volatile storage, in which case this MUST be used as a starting point;
- power adjustment MUST be capable of being reduced or increased by the specified amount in response to RNG-RSP messages;
- if power is adjusted to the maximum value it MUST wrap back to the minimum.

B.7.2.5 Establish IP connectivity

At this point, the BWA CPE Modem MUST invoke DHCP mechanisms (IETF RFC 1541) in order to obtain an IP address and any other parameters needed to establish IP connectivity. The DHCP response MUST contain the name of a file which contains further configuration parameters. Refer to Figure B.7-9.

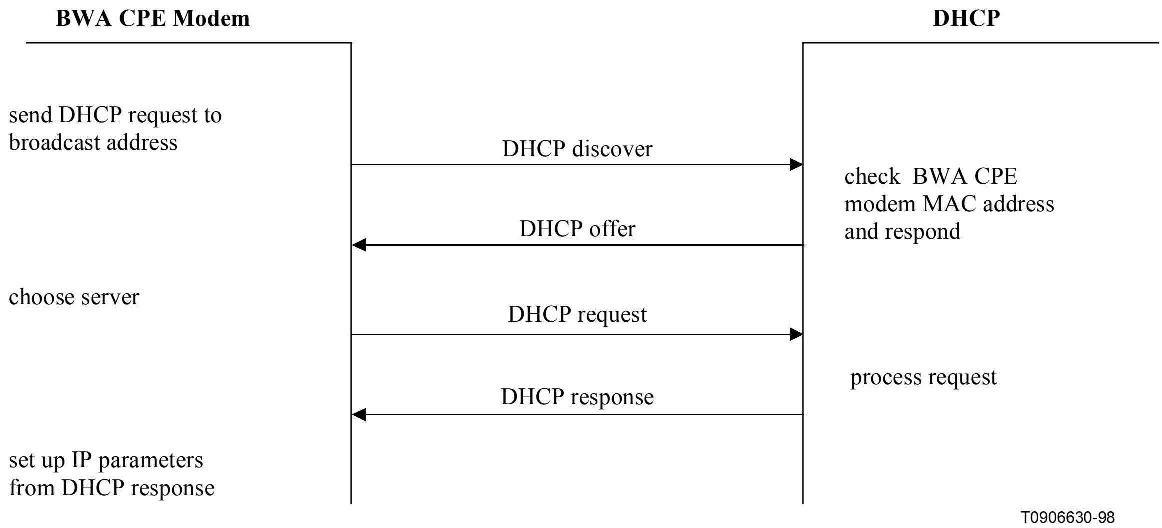


Figure B.7-9/J.116 – Establishing IP connectivity

B.7.2.6 Establish time of day

The BWA CPE Modem and BWA BTS Modem need to have the current date and time. This need not be authenticated and need only be accurate to the nearest second (MCNS2[1]).

This is required for:

- time-stamping logged events which can be retrieved by the management system;
- key management by the security system.

The protocol by which the time of day is retrieved will be as defined in IETF RFC 868. Refer to Figure B.7-10.

The request and response will be transferred using UDP.

The time retrieved from the server (UTC) will be combined with the time offset received from the DHCP response to create the current local time.

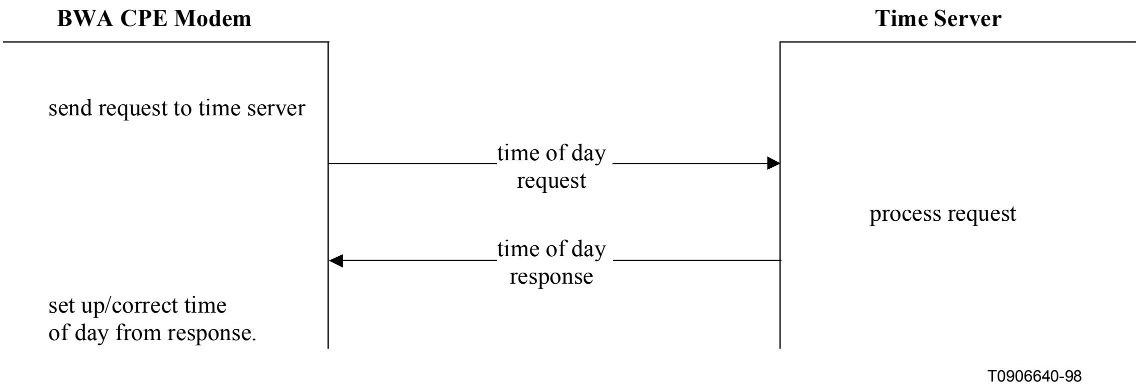


Figure B.7-10/J.116 – Establishing time of day

B.7.2.7 Establish security association

If security is required on the network and no security association has been established, the BWA CPE Modem MUST establish a security association at this point. The IP address of the security server (or servers) MUST be provided as part of the DHCP response. The procedures required are fully defined in MCNS2[1].

B.7.2.8 Transfer Operational Parameters

After the DHCP and security association operations are successful, the modem MUST download the parameter file using TFTP, as shown in Figure B.7-11. The TFTP configuration parameter server is specified by the "siaddr" field of the DHCP response.

The parameter fields required in the DHCP response and the format and content of the configuration file MUST be as defined in clause B.12. Note that these fields are the minimum required for interoperability.

B.7.2.9 Registration

A BWA CPE Modem MUST be authorised to forward traffic into the network once it is initialised, authenticated and configured. Refer to Figure B.7-11.

The configuration parameters downloaded to the BWA CPE Modem MUST include a network access control object (see clause B.12.8.5). If this is set to "no forwarding", the BWA CPE Modem MUST not forward data to the network. It MUST respond to network management requests. This allows the BWA CPE Modem to be configured in a mode in which it is manageable but will not forward data.

The BWA CPE Modem MUST forward the operational parameters to the BWA BTS Modem as part of a registration request. The BWA BTS Modem MUST perform the following operations to confirm the BWA CPE Modem authorisation:

- check the MAC and the authentication signature on the parameter list;
- build a profile for the modem based on the standard configuration settings (see clause B.12);
- assign a service ID based on the classes of service supported;
- reply to the modem registration request.

Vendor-specific configuration settings MUST be ignored (except for inclusion in message authorisation code calculation).

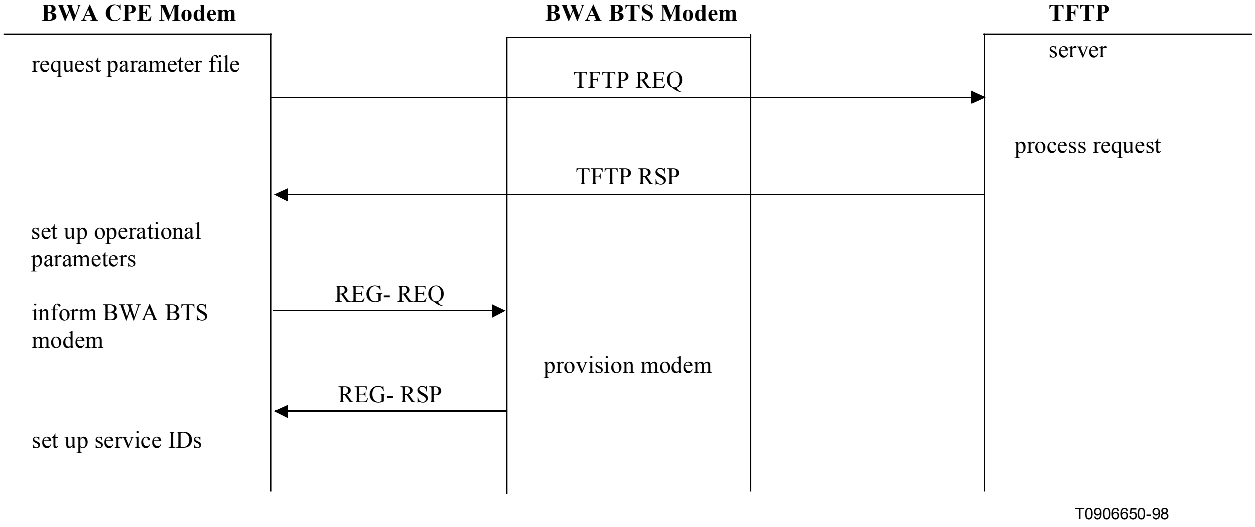


Figure B.7-11/J.116 – Transferring operational parameters and registration

B.7.2.10 Service IDs during BWA CPE Modem Initialisation

After completion of the Registration process (clause B.7.2.9), the BWA CPE Modem will have been assigned Service IDs (SIDs) to match its class of service provisioning. However, the BWA CPE Modem must complete a number of protocol transactions prior to that time (e.g. Ranging, DHCP, etc.), and requires a temporary Service ID in order to complete those steps.

On reception of an Initial Ranging Request, the BWA BTS Modem MUST allocate a temporary SID and assign it to the BWA CPE Modem for initialisation use. The BWA BTS Modem MAY monitor use of this SID and restrict traffic to that needed for initialisation. It MUST inform the BWA CPE Modem of this assignment in the Ranging Response.

On receiving a Ranging Response addressed to it, the BWA CPE Modem MUST use the assigned temporary SID for further initialisation transmission requests until the Registration Response is received.

It is possible that the Ranging Response may be lost after transmission by the BWA BTS modem. The BWA CPE Modem MUST recover by timing out and re-issuing its Initial Ranging Request. Since the BWA CPE Modem is uniquely identified by the source MAC address in the Ranging Request, the BWA BTS Modem MAY immediately re-use the temporary SID previously assigned. If the BWA BTS Modem assigns a new temporary SID, it MUST make some provision for ageing out the old SID that went unused (see clause B.6.3.2.7).

When assigning class-of-service-provisioned SIDs on receiving a Registration Request, the BWA BTS Modem may re-use the temporary SID, assigning it to one of the class of service classes requested. If so, it MUST continue to allow initialisation messages on that SID, since the Registration Response could be lost in transit. If the BWA BTS Modem assigns all-new SIDs for class-of-service provisioning, it MUST age out the temporary SID. The ageing-out MUST allow sufficient time to complete the registration process in case the Registration Response is lost in transit.

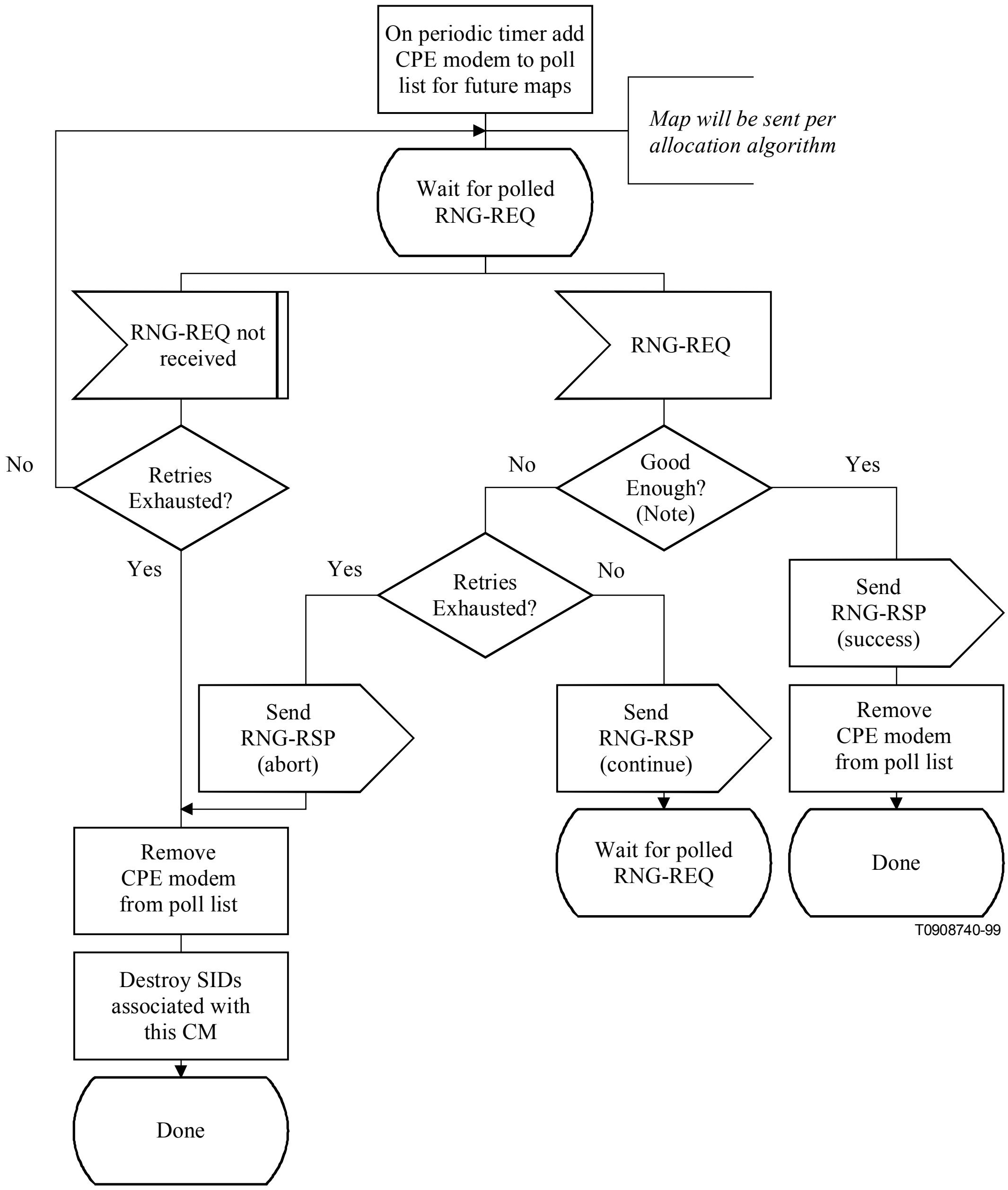
B.7.2.11 Multiple-Channel Support

In the event that more than one downstream signal is present in the system, the BWA CPE Modem MUST operate using the first valid downstream signal that it encounters when scanning. It will be instructed via the parameters in the configuration file (see clause B.12) to shift operation to different downstream and/or upstream frequencies if necessary.

Both upstream and downstream channels MUST be identified where required in MAC management messages using channel identifiers.

B.7.2.12 Remote RF signal level adjustment

RF signal level adjustment at the BWA CPE Modem is performed through a periodic maintenance function using the RNG-REQ and RNG-RSP MAC messages. This is similar to initial ranging and is shown in Figures B.7-12 and B.7-13. On receiving a RNG-RSP, the BWA CPE Modem MUST NOT transmit until the RF signal has been adjusted in accordance with the RNG-RSP and has stabilised (refer to clause B.4).



NOTE – Means Ranging Request is within the tolerance limits of the BTS modem for power and transmit equalization (if supported).

Figure B.7-12/J.116 – Periodic Ranging – BTS Modem

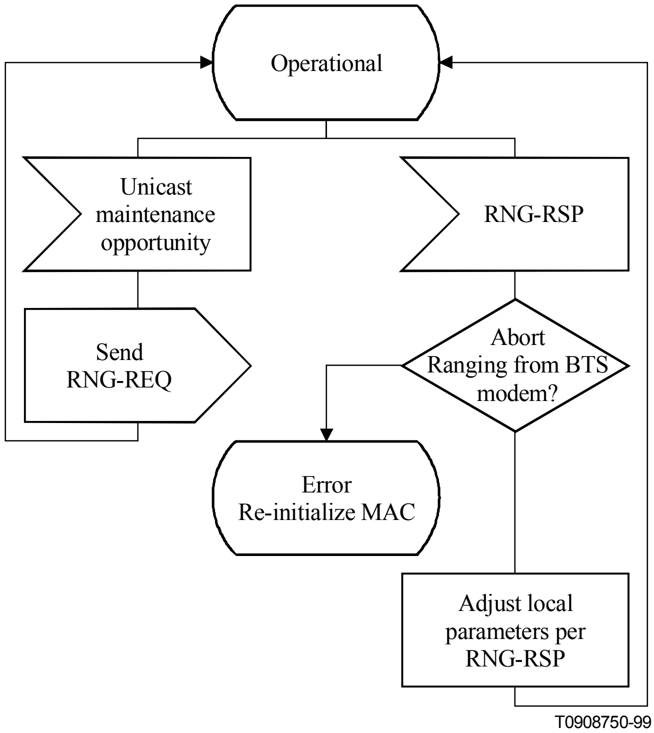


Figure B.7-13/J.116 – Periodic Ranging – BWA CPE Modem View

B.7.2.13 Changing upstream burst parameters

Whenever the BWA BTS Modem is to change any of the upstream burst characteristics, it must provide for an orderly transition from the old values to the new values by all BWA CPE Modems. Whenever the BWA BTS Modem is to change any of the upstream burst values, it MUST:

- Announce the new values in an Upstream Channel Descriptor message. The Configuration Change Count field must be incremented to indicate that a value has changed.

  After transmitting one or more UCD messages with the new value, the BWA BTS Modem transmits a MAP message with a UCD Count matching the new Configuration Change Count. The first interval in the MAP MUST be a data grant of at least 1 millisecond to the null Service ID (zero). That is, the BWA BTS Modem MUST allow one millisecond for BWA CPE modems to change their PMD sublayer parameters to match the new set. This millisecond is in addition to other MAP timing constraints (see clause B.6.4.2).

- The BWA BTS Modem MUST NOT transmit MAPs with the old UCD Count after transmitting the new UCD.

  The BWA CPE Modem MUST use the parameters from the UCD corresponding to the MAP's "UCD Count" for any transmissions it makes in response to that MAP. If the BWA CPE Modem has, for any reason, not received the corresponding UCD, it cannot transmit during the interval described by that MAP.

B.7.2.14 Changing upstream channels

At any time after registration, the BWA BTS Modem MAY direct the BWA CPE Modem to change its upstream channel. This may be done for traffic balancing, noise avoidance, or any of a number of other reasons which are beyond the scope of this specification. Figure B.7-14 shows the procedure that MUST be followed by the BWA BTS Modem. Figure B.7-15 shows the corresponding procedure at the BWA CPE Modem.

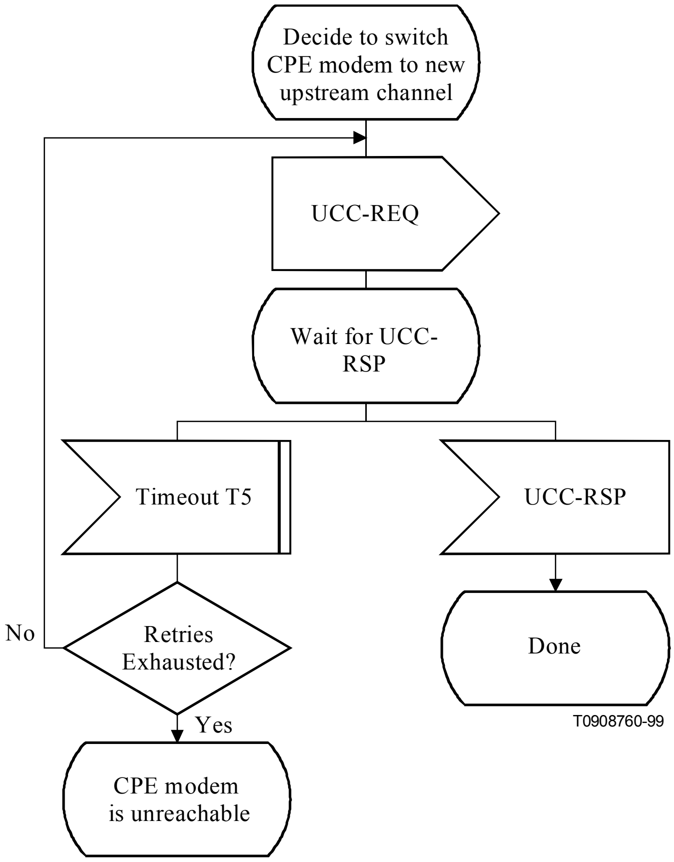


Figure B.7-14/J.116 – Changing upstream channels: BWA BTS Modem View

Note that if the BWA BTS Modem retries the UCC-REQ, the BWA CPE Modem may have already changed channels (if the UCC-RSP was lost in transit). Consequently, the BWA BTS Modem MUST listen for the UCC-RSP on both the old and the new channels.

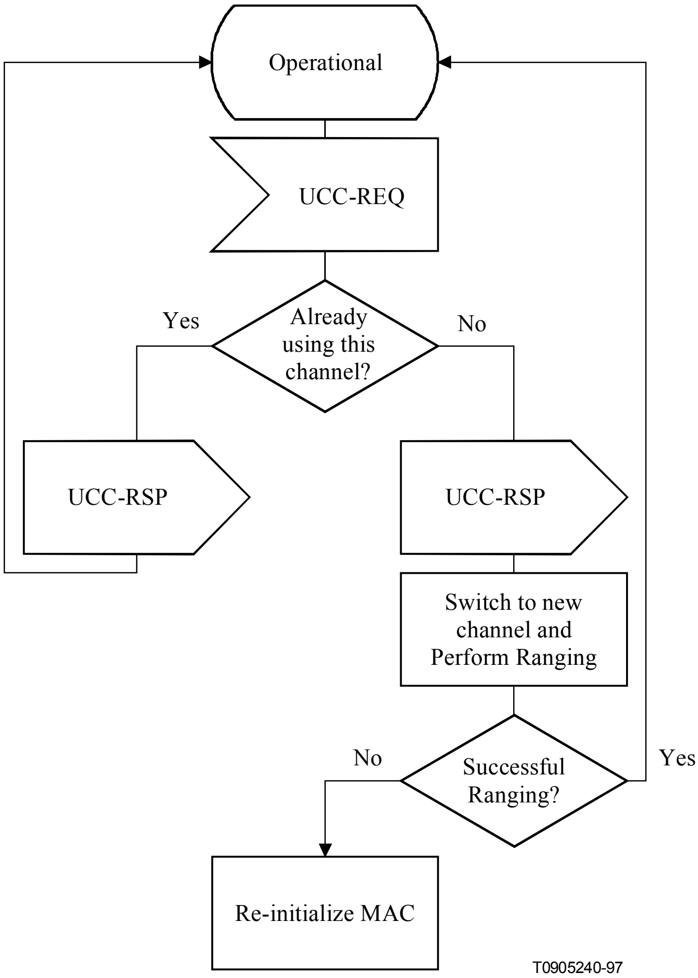


Figure B.7-15/J.116 – Changing upstream channels: BWA CPE Modem View

The BWA CPE Modem MUST successfully establish initial ranging on a new channel before using that channel. It MUST NOT perform re-registration, since its provisioning and MAC domain remain valid on the new channel. If the BWA CPE Modem has previously established ranging on the new channel, and if that ranging on that channel is still current (T4 has not elapsed since the last successful ranging), then the BWA CPE Modem MAY use cached ranging information and may omit initial ranging.

B.7.2.15 Fault detection and recovery

Fault detection and recovery occurs at multiple levels:

- at the physical level, FEC is used to correct errors where possible – refer to clause B.4 for details;
- the MAC protocol protects against errors through the use of checksum fields across both the MAC Header and the data portions of the packet – refer to clause B.6 for details;
- all MAC management messages are protected with a CRC covering the entire message, as defined in clause B.6. Any message with a bad CRC MUST be discarded by the receiver.

Table B.7-1 shows the recovery process that MUST be taken following the loss of a specific type of MAC message.

Table B.7-1/J.116 – Recovery process on loss of specific MAC messages

Message name	Action following message loss
SYNC	The BWA CPE Modem can lose SYNC messages for a period of the loss SYNC interval (see clause B.11) before it has lost synchronisation with the network. When this occurs, it follows the same procedures to reacquire connectivity as during initialisation.
UCD	A BWA CPE Modem MUST receive a valid UCD before transmitting on the upstream. Failure to receive a valid UCD within the timeout period MUST cause the modem to reset and reinitialise its MAC connection.
MAP	A BWA CPE Modem MUST NOT transmit without a valid upstream bandwidth allocation. If a MAP is missed due to error, the BWA CPE Modem MUST NOT transmit for the period covered by the MAP. Failure to receive a valid MAP within the timeout period MUST cause the modem to reset and reinitialise its MAC connection.
RNG-REQ RNG-RSP	If a BWA CPE Modem fails to receive a valid ranging response within a defined timeout period after transmitting a request, the request MUST be retried a number of times (as defined in clause B.11). Failure to receive a valid ranging response after the requisite number of attempts MUST cause the modem to reset and reinitialise its MAC connection.
REG-REQ REG-RSP	If a BWA CPE Modem fails to receive a valid registration response within a defined timeout period after transmitting a request, the request will be retried a number of times (as defined in clause B.11). Failure to receive a valid registration response after the requisite number of attempts will cause the modem to reset and reinitialise its MAC connection.
UCC-REQ UCC-RSP	If a BWA BTS Modem fails to receive a valid upstream channel change response within a defined timeout period after transmitting a request, the request MUST be retried a number of times (as defined in clause B.11). Failure to receive a valid response after the requisite number of attempts MUST cause the BWA BTS Modem to consider the BWA CPE Modem as unreachable.

Messages at the network layer and above are considered to be data packets by the MAC Sublayer. These are protected by the CRC field of the data packet and any packets with bad CRCs are discarded. Recovery from these lost packets is in accordance with the upper layer protocol.

B.7.2.16 Prevention of unauthorised transmissions

A BWA CPE Modem SHOULD include a means for terminating RF transmission if it detects that its own carrier has been on continuously for longer than the longest possible valid transmission.

B.8 Supporting future new BWA CPE modem capabilities

B.8.1 Setting up communications on an enhanced basis

In the future, new types of BWA CPE Modem or BWA BTS Modem with enhanced characteristics may be introduced. Future-proofing is provided, in the protocols described herein, to permit these new types of BWA CPE Modem or BWA BTS Modem to set up communication on an enhanced basis.

Two methods are provided to accomplish this: one for use when the downstream channel supports upstream channels of varying capability and the other for the case where enhanced downstream channels are available.

B.8.1.1 Upstream enhanced/downstream standard

The procedure MUST be as follows:

a) the enhanced BWA CPE Modem acquires a standard downstream BWA BTS Modem signal;

b) the BWA CPE Modem receives and interprets upstream channel descriptor (UCD) messages forwarded from the BWA BTS Modem until it finds one for a channel with the enhanced characteristics which it wishes to use. It joins the upstream transmission stream of this channel which has been assigned to enhanced BWA CPE Modems in accordance with the information in the downstream BWA BTS Modem signal.

B.8.1.2 Downstream enhanced/upstream enhanced or standard

The procedure MUST be as follows:

a) the enhanced BWA CPE Modem acquires a standard downstream BWA BTS Modem signal;

b) the BWA CPE Modem receives and interprets upstream channel descriptor (UCD) messages forwarded from the BWA BTS Modem until it finds one for a channel with the best match to the enhanced characteristics which it wishes to use. It joins the upstream transmission stream of this channel which has been assigned to enhanced BWA CPE Modem in accordance with the information in the downstream BWA BTS Modem signal;

c) the enhanced BWA CPE Modem interacts with the provisioning server for the purposes of agreeing upon the operating frequencies, modulation, data rate and other characteristics for enhanced operation;

d) the enhanced BWA CPE Modem changes operating frequencies and other characteristics accordingly, if necessary, and commences enhanced operation on a different downstream channel if necessary under conditions that will not interfere with the standard BWA CPE Modems;

e) the BWA CPE Modem acquires the new downstream BWA BTS Modem signal and waits on appropriate UCD on this new channel.

B.8.2 Downloading BWA CPE modem operating software

A BWA BTS Modem SHOULD be capable of being remotely reprogrammed in the field via a software download via the network.

The BWA CPE modem device MUST be capable of being remotely reprogrammed in the field via a software download over the network. This software download capability MUST allow the functionality of the BWA CPE modem to be changed without requiring that BWA system personnel physically revisit and reconfigure each unit. It is expected that this field programmability will be used to upgrade BWA CPE modem software to improve performance, accommodate new functions and features (such as enhanced class of service support), correct any design deficiencies discovered in the software, and to allow a migration path as the Data Over BWA Interface Specification evolves.

The mechanism used for download MUST be TFTP file transfer. The mechanism by which transfers are secured and authenticated is in MCNS2[1]. The transfer MUST be initiated in one of two ways:

- an SNMP manager requests the BWA CPE Modem to upgrade;
- the configuration parameter file delivered to the BWA CPE Modem from the provisioning server MUST include the desired filename from which the desired software image can be retrieved. If the filename does not match the current software image of the BWA CPE Modem, the BWA CPE Modem MUST request the specified file from a TFTP server.

The BWA CPE Modem MUST write the new software image to non-volatile storage. Once the file transfer is complete, the BWA CPE Modem MUST restart itself with the new code image.

If the BWA CPE Modem is unable to complete the file transfer for any reason, it MUST remain capable of accepting new software downloads, even if power is interrupted between attempts. The BWA CPE Modem MUST log the failure and MAY report it asynchronously to the network manager.

Following upgrade of the operational software, the BWA CPE Modem MAY need to follow one of the procedures described above in order to change channels to use the enhanced functionality.

If the BWA CPE Modem is to continue to operate in the same upstream and downstream channels as before the upgrade, then it MUST be capable of inter-working with other BWA CPE Modems which MAY be running previous releases of software.

Where software has been upgraded to meet a new version of the specification, then it is critical that it MUST inter-work with the previous version in order to allow a gradual transition of units on the network.

The periodic SYNC message transmitted on the downstream channel MUST indicate the protocol revision at which the channel is operating.

B.9 Provision for other future capabilities

It is anticipated that BWA CPE modem networks will, in the future, support capabilities that cannot be adequately defined today. These capabilities may include:

- new physical-layer modulation encoding;
- improvements to, or new configuration settings within, the defined physical-layer encoding;
- differing traffic flows and classes of service.

It is the intent of this specification to provide for interoperability with future devices and networks to whatever extent is practical. The minimum level of interoperability is that future-capability modems and modems conforming to this specification are assigned to different frequency bands, and all modems can automatically scan to find a congenial frequency band.

B.9.1 Anticipated physical-layer changes

Existing MAC signalling provides for optional transmitter equalisation (see B.6.3.2.5).

Other forms of upstream transmission manipulation, such as Tomlinson-Harashima precoding, may be developed in the future. Signalling to support such functions can be added as optional TLV-encodings for the Ranging Response message.

This configuration setting can be phased into existing networks without placing new requirements on existing devices.

When developing a new network, it may be necessary to know modem capabilities before coming to rely on a feature like this. The "Modem Capabilities" mask, exchanged as part of the BWA CPE Modem-to-BWA BTS Modem registration process (see B.6.3.2.7) is intended to provide this information.

B.9.1.1 Adding upstream channel and burst configuration settings

In future, configuration settings may be provided for new upstream burst characteristics:

- trellis-coded modulation (2 bits/symbol and 4 bits/symbol);
- interleaving within a burst.

These are defined through new encodings of the Upstream Channel Descriptor. A BWA CPE Modem which finds characteristics which it does not implement is required to either abstain from that burst type, or to find a different upstream channel (see B.8.1.1). This is also controllable by administrative policy if enough commonality is present to complete the registration process.

As with transmission precoding, a modem-capabilities flag may be needed if the BWA BTS Modem is to choose least-common-denominator capability.

B.9.1.1.1 Channel burst parameters for advanced modems

Configuration settings for channel burst parameters for advanced modems are given in Table B.9-1.

Table B.9-1/J.116 – Channel burst parameters for advanced modems

Parameter	Configuration settings
Modulation (additional configuration settings)	Trellis Coded Modulation available: 1) 8 PSK – 2 bits/s (analogous to QPSK); 2) 32 QAM – 4 bits/s (analogous to 16-QAM) 2 encoder configuration settings available for each.
Interleaving N rows by M columns transmitter fills columns	 N = 0 to 255; 0 = no interleaving M = 1 to 256
Tomlinson-Harashima Precoding	1) TH Precoding 2) Conventional Transmit FIR Equalisation 3) None

It should be possible to program these capabilities separately to users on a given channel. For example, two users should be able to be commanded to operate at a given channel frequency and symbol rate, with one user having any or all of these features: 8PSK TCM, Interleaving, and TH Precoding; while the other user employs QPSK and none of the other features (i.e. this user is not an advanced BWA CPE modem).

B.9.1.2 Downstream channel improvements

Downstream channel improvements may require additional frequencies to implement for interoperability. The modem initialisation process defined herein provides that if the BWA CPE Modem is unable to complete satisfactory exchanges with the BWA BTS Modem then it will scan for a more suitable frequency (see B.8.1.2).

B.9.2 New network service requirements

The types of network service expected on a BWA network are apt to change over the lifetime of equipment conforming to this specification. This specification anticipates use of ATM-style traffic parameters by giving the BWA BTS Modem centralised control over bandwidth allocation and jitter. Future networks may include classes of data other than those explicitly provided (802-like and ATM). These may be implemented by using the Reserved code point in the MAC FC field. Because this specification does not require a particular bandwidth allocation algorithm, future algorithms may be developed which take into account policies and traffic types that are not yet well-understood.

B.9.2.1 Multicast Service IDs

Multicast Service IDs provide extensibility to the interval usage codes that are defined herein in the upstream bandwidth allocation map. The multicast ID reflects, not just group membership, but also the access rules that apply to whatever interval is assigned to that ID. The following examples of Request/Data IEs illustrate some of the possibilities for use of a particular ID:

- the grant is for contention space for all high-priority (as defined locally) data PDUs from a select group of BWA CPE modems;
- the grant is for ATM cells only.

It may be necessary to develop an extension to the MAC signalling protocol to distribute the definition of attributes associated with particular multicast Service IDs.

B.9.2.2 RSVP support for upstream traffic

The Resource ReSerVation Protocol (RSVP) is a resource reservation setup protocol currently being standardised by the Internet Engineering Task Force. RSVP provides receiver-initiated setup of resource reservations for multicast and unicast data flows. This clause serves to anticipate and guide the definition of new MAC management messages to support resource reservation for upstream traffic in the Data-over-BWA context.

RSVP assumes the implementation of two modules on each RSVP-capable node to forward data packets: the "packet classifier" and the "packet scheduler". The packet classifier determines the route and class-of-service class for each packet, and sends the packet to the packet scheduler. The RSVP packet classifier uses a "filter spec" (which matches a particular source IP address and TCP/UDP port number) to classify and restrict traffic that consumes reservation resources. The packet scheduler makes packet forwarding decisions (e.g. queuing decisions) to achieve the promised class of service on the interface. The RSVP packet scheduler uses a "flow spec" (which identifies token bucket parameters, peak data rate, etc.) to identify the desired class of service.

In the context of RSVP for upstream traffic in the data-over-BWA system, it is desirable for the BWA CPE Modem to perform the "packet classifier" function; however, the BWA BTS Modem should perform most of the "packet scheduler" function. The support for this split of functions suggests the future definition of three new MAC management messages: "Dynamic Service Addition", "Dynamic Service Deletion", and "Dynamic Service Response".

The Dynamic Service Addition message is periodically transmitted from the BWA BTS Modem to the BWA CPE Modem to announce the allocation of a new SID. The Dynamic Service Addition message contains the new SID value, and type/length/value fields which can encode the RSVP filter specification and RSVP "cleanup timeout" interval (to support the RSVP "soft state" approach). The BWA CPE Modem is expected to use the new SID exclusively for upstream traffic that matches the filter specification. The BWA CPE Modem should assume that the new SID is refreshed by the receipt of another Dynamic Service Addition message within the cleanup timeout interval; otherwise, the SID is ignored by the BWA CPE Modem at the conclusion of the interval.

The Dynamic Service Deletion message is transmitted from the BWA BTS Modem to the BWA CPE Modem to delete an unused SID immediately (to support the RSVP explicit "teardown" message). The Dynamic Service Response message is transmitted from the BWA CPE Modem to the BWA BTS Modem to acknowledge receipt of a Dynamic Service Addition or Dynamic Service Deletion message.

The interaction between RSVP "Path" and "Resv" messages, and the Dynamic Service Addition and Dynamic Service Response messages, is proposed to be as follows:

1) the data flow source-node generates an RSVP Path message, and sends the message toward the data flow destination-node;

2) the BWA BTS Modem intercepts the downstream RSVP Path message, stores "path state" from the message, updates the "previous hop address" in the message, and forwards the message;

3) the BWA CPE Modem forwards the downstream RSVP Path message to the destination-node without processing;

4) the data flow destination-node receives the RSVP Path message, and replies with an RSVP Resv message to request a reservation of resources for the data flow from the source-node to itself. The RSVP Resv message is sent to the "previous hop" of the Path message – the BWA BTS Modem;

5) the BWA CPE Modem forwards the upstream RSVP Resv message to the BWA BTS Modem without processing;

6) the BWA BTS Modem receives the upstream RSVP Resv message, and processes the message flow spec using its "admission control" and "policy control" modules (in cooperation with the BWA BTS Modem upstream bandwidth scheduler). The rest of this subclause assumes that the reservation message is accepted by the BWA BTS Modem;

7) the BWA BTS Modem sends the "Dynamic Service Addition" MAC message to the BWA CPE Modem. The message includes a new SID and the "filter spec" from the RSVP Resv message;

8) the BWA CPE Modem receives the "Dynamic Service Addition" MAC message, stores the new SID and "filter spec", and sends the "Dynamic Service Response" MAC message to the BWA BTS Modem;

9) the BWA BTS Modem receives the "Dynamic Service Response" MAC message, and forwards the RSVP Resv message to its "previous hop".

B.9.3 PID filtering capability

This specification uses a single well-known PID for all data-over-BWA traffic. BWA CPE Modems MAY use additional PIDs for differentiation of traffic types or to provide streams to individual BWA CPE Modems. PID assignments MAY be facilitated by the appropriate MAC control message extensions. As an example, this could facilitate services that use MPEG packet-level encryption. Any such services are beyond the scope of this version of the specification.

An additional modem capability configuration setting could be added in the Registration Request (REG-REQ) message to indicate the number of PIDs, in addition to the well-known PID, that the BWA CPE Modem can filter. A "0" would indicate that the BWA CPE Modem can only filter on the well-known PID.

An extension to the encodings in the Registration Response (REG-RSP) could be used to assign to a BWA CPE Modem additional PIDs on which to filter.

B.10 Well-known addresses

B.10.1 MAC addresses

MAC addresses described here are defined using the Ethernet/ISO/IEC 8802-3 convention as bit-little-endian.

The following multicast address MUST be used to address the set of all BWA CPE Modem MAC sublayers; for example, when transmitting Allocation Map PDUs.

01-E0-2F-00-00-01

The following multicast address MUST be used to address all BWA BTS Modem within the MAC-sublayer domain:

01-E0-2F-00-00-02

Note that in nearly all cases the unicast BWA BTS Modem address is preferred. The address range

01-E0-2F-00-00-03 through 01-E0-2F-00-00-0F

is reserved for future definition. Frames addressed to any of these addresses SHOULD NOT be forwarded out of the MAC-sublayer domain.

B.10.2 MAC Service IDs

The following MAC Service IDs have assigned meanings. Those not included in this table are available for assignment, either by the BWA BTS Modem or administratively.

0x0000 Addressed to no BWA CPE Modem.

0x3FFF Addressed to all BWA CPE Modems.

0x3FF1-0x3FFE Addressed to all BWA CPE Modems. Available for small data PDUs, as well as requests (used only with request/data IEs). The last digit indicates the frame length and transmission opportunities as follows:

0x3FF1 Within the interval specified, a transmission may start at any mini-slot, and must fit within one mini-slot.

0x3FF2 Within the interval specified, a transmission may start at every other mini-slot, and must fit within two mini-slots (e.g. a station may start transmission on the first mini-slot within the interval, the third mini-slot, the fifth, etc.).

0x3FF3 Within the interval specified, a transmission may start at any third mini-slot, and must fit within three mini-slots (e.g. starts at first, fourth, seventh, etc.).

0x3FF4 Starts at first, fifth, ninth, etc.

. . .

0x3FFD Starts at first, fourteenth (14th), twenty-seventh (27th), etc.

0x3FFE Within the interval specified, a transmission may start at any 14th mini-slot, and must fit within 14 mini-slots.

B.10.3 MPEG PID and table_id

All BWA data MUST be carried in MPEG-2 packets with the header PID field set to 0x1FFE.

The MPEG-2 Private Sections carrying the BWA Frames MUST have the first byte (table_id) set to 0x40.

B.11 Parameters and constants

System	Name	Time reference	Minimum value	Default value	Maximum value
BWA BTS Modem	Sync Interval	Time between transmission of SYNC messages (ref. B.6.3.2.1)			200 ms
BWA BTS Modem	UCD Interval	Time between transmission of UCD messages (ref. B.6.3.2.2)			2 s
BWA BTS Modem	Max MAP Pending	The number of mini-slots that a BWA BTS Modem is allowed to map into the future (ref. B.6.3.2.3)			4096 mini-slot times
BWA BTS Modem	Ranging Interval	Time between transmission of broadcast Ranging requests (ref. B.6.3.2.4)			2 s
BWA CPE Modem	Lost Sync Interval	Time since last received Sync message before synchronisation is considered lost			600 ms
BWA CPE Modem	Contention Ranging Retries	Number of Retries on contention Ranging Requests (ref. B.7.2.4)	16		
BWA CPE Modem, BWA BTS Modem	Invited Ranging Retries	Number of Retries on inviting Ranging Requests (ref. B.7.2.4)	16		
BWA CPE Modem	Request Retries	Number of retries on bandwidth allocation requests	16		
BWA CPE Modem	Data Retries	Number of retries on immediate data transmission	16		
BWA BTS Modem	BWA CPE Modem MAP processing time	Time provided between arrival of the last bit of a MAP at a BWA CPE Modem and effectiveness of that MAP (ref. B.6.4.1)	200 µs		
BWA BTS Modem	BWA CPE Modem Ranging Response processing time	Minimum time allowed for a BWA CPE Modem following receipt of a ranging response before it is expected to reply to an invited ranging request	1 ms		
BWA CPE Modem	T1	Wait for UCD timeout			5 * UCD interval maximum value
BWA CPE Modem	T2	Wait for broadcast ranging timeout			5 * ranging interval
BWA CPE Modem	T3	Wait for ranging response	50 ms	200 ms	200 ms
BWA CPE Modem	T4	Wait for unicast ranging opportunity			5 * ranging interval
BWA BTS Modem	T5	Wait for Upstream Channel Change response			2 s
BWA CPE Modem BWA BTS Modem	Mini-slot size	Size of mini-slot for upstream transmission. Must be a power of 2 (in units of the Timebase Tick)	32 symbol times		
BWA CPE Modem BWA BTS Modem	Timebase Tick	System timing unit	6.25 µs		

B.12 BWA CPE Modem configuration interface specification

B.12.1 DHCP fields used by the BWA CPE Modem

The following fields are required in the DHCP request from the BWA CPE Modem.

- The hardware type SHOULD be set to Ethernet.
- The hardware address of the BWA CPE Modem (used as the key to identify the BWA CPE Modem during the DHCP process).

The following fields are required in the DHCP response returned to the BWA CPE Modem.

- The IP address to be used by the BWA CPE Modem.
- The subnet mask to be used by the BWA CPE Modem.
- If the DHCP server is on a different network (requiring a relay agent), then the relay agent MUST set the gateway address field of the DHCP response.
- The name of the BWA CPE Modem configuration file to be read from the TFTP server by the BWA CPE Modem.
- The time offset of the BWA CPE Modem from Universal Coordinated Time (UTC) – used by the BWA CPE Modem to calculate the local time to use in time-stamping error logs.
- Time-server option – provides a list of (IETF RFC 868) time-servers from which the current time may be obtained.
- The IP address of the next server to use in the bootstrap process (TFTP server) is returned in the siaddr field.
- The IP address of the security server SHOULD be set if security is required. This is encoded using the code 128 (which is reserved for site specific information per reference IETF RFC 1533) as shown below.

type	length	value
128	4	ip1,ip2,ip3,ip4

B.12.2 BWA CPE Modem binary configuration file format

The BWA CPE Modem-specific configuration data MUST be contained in a file which is downloaded to the BWA CPE Modem via TFTP. This is a binary file in the same format defined for DHCP vendor extension data (IETF RFC 1533).

It MUST consist of a number of configuration settings (1 per parameter) each of the form

type: length: value

where: type is a single-octet identifier which defines the parameter;

length is a single octet containing the length of the value field (not including type and length fields);

value is from one to 254 octets containing the specific value for the parameter.

The configuration settings MUST follow each other directly in the file, which is a stream of octets (no record markers).

Configuration settings are divided into three types:

- Standard configuration settings which MUST be present.
- Standard configuration settings which MAY be present.
- Vendor-specific configuration settings.

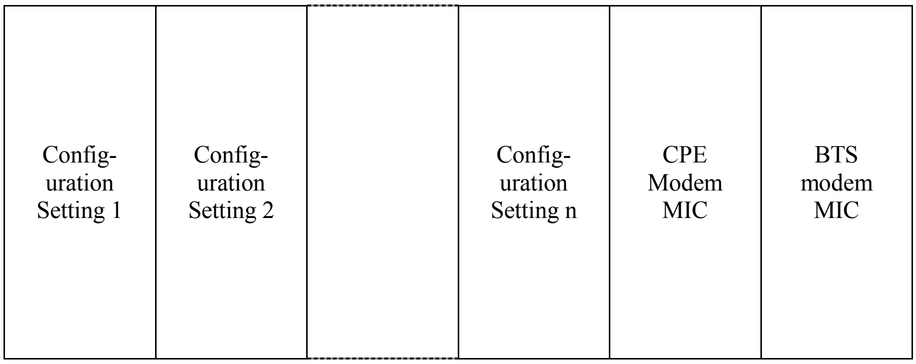
BWA CPE Modems MUST be capable of processing all standard configuration settings.

Authentication of the provisioning information is provided by two message integrity check (MIC) configuration settings, BWA CPE Modem MIC and BWA BTS Modem MIC.

- BWA CPE Modem MIC is a digest which ensures that the data sent from the provisioning server were not modified en route. This is NOT an authenticated digest (it does not include any shared secret).
- BWA BTS Modem MIC is a digest used to authenticate the provisioning server to the BWA BTS Modem during registration. It is taken over a number of fields one of which is a shared secret between the BWA BTS Modem and the provisioning server.

Use of the BWA CPE Modem MIC allows the BWA BTS Modem to authenticate the provisioning data without needing to receive the entire file.

Thus the file structure is of the form shown in Figure B.12-1:



NOTE – Not all configuration settings need to be present in a given file.

Figure B.12-1/J.116 – Binary configuration file format

B.12.3 Configuration file settings

The following configuration settings MUST be included in the configuration file and MUST be supported by all BWA CPE Modems.

- Downstream Frequency Configuration Setting.
- Upstream Channel ID Configuration Setting.
- Network Access Configuration Setting.
- End Configuration Setting.

The following configuration settings MAY be included in the configuration file and if present MUST be supported by all BWA CPE Modems.

- Class of Service Configuration Setting.
- Vendor ID Configuration Setting.
- Software Upgrade Filename Configuration Setting.
- SNMP Write-Access Control.
- SNMP MIB Object.
- Pad Configuration Setting.

The following configuration settings MAY be included in the configuration file and if present MAY be supported by a BWA CPE Modem.

- Vendor-Specific Configuration Settings.

B.12.4 Configuration file creation

The sequence of operations required to create the configuration file is as shown in Figures B.12-2 through B.12-5.

1) Create the type/length/value entries for all the parameters required by the BWA CPE Modem.

type, length, value for parameter 1
type, length, value for parameter 2
type, length, value for parameter n

Figure B.12-2/J.116 – Create TLV entries for parameters required by the BWA CPE Modem

2) Calculate the BWA CPE Modem message integrity check (MIC) configuration setting as defined in B.12.5 and add to the file following the last parameter using code and length values defined for this field.

type, length, value for parameter 1
type, length, value for parameter 2
type, length, value for parameter n
type, length, value for CPE modem MIC

Figure B.12-3/J.116 – Add BWA CPE Modem MIC

3) Calculate the BWA BTS Modem message integrity check (MIC) configuration setting as defined in B.12.6 and add to the file following the BWA CPE Modem MIC using code and length values defined for this field.

type, length, value for parameter 1
type, length, value for parameter 2
type, length, value for parameter n
type, length value for CPE modem MIC
type, length value for BTS modem MIC

Figure B.12-4/J.116 – Add BWA BTS Modem MIC

4) Add the end of data marker.

type, length, value for parameter 1
type, length, value for parameter 2
type, length, value for parameter n
type, length value for CPE modem MIC
type, length value for BTS modem MIC
end of data marker

Figure B.12-5/J.116 – Add end of data marker

B.12.5 BWA CPE Modem MIC calculation

The BWA CPE Modem message integrity check configuration setting MUST be calculated by performing an MD5 digest over the following configuration setting fields in the order shown, treated as if they were contiguous data:

- Downstream Frequency Configuration Setting.
- Upstream Channel ID Configuration Setting.
- Network Access Configuration Setting.
- Class of Service Configuration Setting.
- Software Upgrade Filename Configuration Setting.
- SNMP Write-Access Control.
- SNMP MIB Object.
- Vendor ID Configuration Setting.
- Vendor-Specific Configuration Settings.

The digest MUST be added to the configuration file as its own configuration setting field using the BWA CPE Modem MIC Configuration Setting encoding.

On receipt of a configuration file, the BWA CPE Modem MUST recompute the digest and compare it to the BWA CPE Modem MIC configuration setting in the file. If the digests do not match then the configuration file MUST be discarded.

B.12.6 BWA BTS Modem MIC calculation

The BWA BTS Modem message integrity check configuration setting MUST be calculated by performing an MD5 digest over the following configuration setting fields in the order shown, treated as if they were contiguous data:

- Downstream Frequency Configuration Setting.
- Upstream Channel ID Configuration Setting.
- Network Access Configuration Setting.
- Class of Service Configuration Setting.
- Vendor ID Configuration Setting.
- Vendor specific Configuration Settings.
- BWA CPE Modem MIC Configuration Setting.
- Authentication string.

The digest MUST be added to the configuration file as its own configuration setting field using the BWA BTS Modem MIC Configuration Setting encoding.

The authentication string is a shared secret between the provisioning server (which creates the configuration files) and the BWA BTS Modem. It allows the BWA BTS Modem to authenticate the BWA CPE Modem provisioning.

The mechanism by which the shared secret is managed is up to the system operator.

On receipt of a configuration file, the BWA CPE Modem MUST forward the BWA BTS Modem MIC as part of the registration request (REG-REQ).

On receipt of a REG-REQ, the BWA BTS Modem MUST recompute the digest over the included fields and the authentication string and compare it to the BWA BTS Modem MIC configuration setting in the file. If the digests do not match, the registration request MUST be rejected by setting the authentication failure result in the registration response status field.

B.12.6.1 Digest calculation

The digest fields MUST be calculated using the mechanism defined in IETF RFC 2104.

B.12.7 Registration configuration settings

The following configuration settings are used in the registration messages. Refer to B.6.3.2 for details on these messages.

Registration Request

- Downstream Frequency Configuration Setting.
- Upstream Channel ID Configuration Setting.
- Network Access Configuration Setting.
- Class of Service Configuration Setting.
- Modem Capabilities Configuration Setting.
- Vendor ID Configuration Setting.
- Vendor-specific extensions.
- BWA CPE Modem MIC.
- BWA BTS Modem MIC.
- Modem IP address.

Registration Response

- Class of Service Configuration Setting.
- Modem Capabilities Configuration Setting.
- Vendor ID Configuration Setting.
- Vendor-Specific extensions.

B.12.8 Encodings

The following type/length/value encodings MUST be used in both the configuration file and in BWA CPE Modem registration requests and BWA BTS Modem responses. All multi-octet quantities are in network-byte order, i.e. the octet containing the most-significant bits is the first transmitted on the wire.

The following configuration settings MUST be supported by all BWA CPE Modems which are compliant with this specification.

B.12.8.1 End-of-data marker

This is a special marker for end of data.

It has no length or value fields.

type
255

B.12.8.2 Pad configuration setting

This has no length or value fields and is only used following the end of data marker to pad the file to an integral number of 32-bit words.

type
0

B.12.8.3 Downstream frequency configuration setting

The receive frequency to be used by the BWA CPE Modem. It is an override for the channel selected during scanning. This is the centre frequency of the downstream channel in Hz stored as a 32-bit binary number.

type	length	rx frequency
1	4	rx1 rx2 rx3 rx4

Valid Range

The receive frequency MUST be a multiple of 62 500 Hz.

B.12.8.4 Upstream channel ID configuration setting

The upstream channel ID which the BWA BTS Modem MUST use. The BWA CPE Modem MUST listen on the defined downstream channel until an upstream channel description message with this ID is found. It is an override for the channel selected during initialisation.

type	length	value
2	1	channel ID

B.12.8.5 Network access control object

If the value field is a 1 this BWA CPE Modem is allowed access to the network; if a 0 it is not.

type	length	on/off
3	1	1 or 0

B.12.8.6 Class of service configuration setting

This field defines the parameters associated with a class of service. It is somewhat complex in that it is composed of a number of encapsulated type/length/value fields. The encapsulated fields define the particular class of service parameters for the class of service in question. Note that the type fields defined are only valid within the encapsulated class of service configuration setting string. A single class of service configuration setting is used to define the parameters for a single service class. Multiple class definitions use multiple class of service configuration setting sets.

type	length	value
4	n	

B.12.8.6.1 Internal class of service encodings

B.12.8.6.1.1 Class ID

The value of the field specifies the identifier for the class of service to which the encapsulated string applies.

type	length	value
1	1	

Valid Range

The class ID MUST be in the range 1 to 16.

B.12.8.6.1.2 Maximum downstream rate configuration setting

The value of the field specifies the maximum data rate in bit/s allowed from this service class on the downstream path. That is, it is the peak data rate for Packet PDU data (including destination MAC address and the CRC) over a one-second interval. This is a limit on the modem, not a guarantee that this rate is available.

type	length	value
2	4	

B.12.8.6.1.3 Maximum upstream rate configuration setting

The value of the field specifies the maximum data rate in bit/s allowed from this service class on the upstream channel. That is, it is the peak data rate for Packet PDU data (including destination MAC address and the CRC) over a one-second interval. This is a limit on the modem, not a guarantee that this rate is available.

type	length	value
3	4	

B.12.8.6.1.4 Upstream channel priority configuration setting

The value of the field specifies the relative priority assigned to this service class for data transmission in the upstream channel. Higher numbers indicate higher priority.

type	length	value
4	1	

Valid Range

$0 \rightarrow 7$

B.12.8.6.1.5 Guaranteed minimum upstream channel data rate configuration setting

The value of the field specifies the data rate in bit/s which will be guaranteed to this service class on the upstream channel.

type	length	value
5	4	

B.12.8.6.1.6 Maximum upstream channel transmit burst configuration setting

The value of the field specifies the maximum transmit burst (in units of mini-slots) which this service class is allowed on the upstream channel.

type	length	value
6	2	255

Valid Range

0 → 255 for initial version.

NOTE – The 2-byte length field is retained to support possible future expansion of allowed burst sizes.

Table B.12-1/J.116 – Sample class of service encoding

Type	Length	Value (sub)type	Length	Value	
4	28				class of service configuration setting
		1	1	1	service class 1
		2	4	10 000 000	max. forward rate of 10 Mbit/s
		3	4	2 000 000	max. return rate of 2 Mbit/s
		4	1	5	return path priority of 5
		5	4	64 000	min guaranteed 64 kbit/s
		6	2	100	max. Tx burst of 100 mini-slots
4	28				class of service configuration setting
		1	1	2	service class 2
		2	4	5 000 000	max. forward rate of 5 Mbit/s
		3	4	1 000 000	max. return rate of 1 Mbit/s
		4	1	3	return path priority of 3
		5	4	32 000	min guaranteed 32 kbit/s
		6	2	50	max. Tx burst of 50 mini-slots

B.12.8.7 CPE Modem capabilities configuration setting

The value field describes the capabilities of a particular modem, i.e. those OPTIONAL features which the modem can support. It is composed of a number of encapsulated type/length/value fields. The encapsulated fields define the specific capabilities for the modem in question. Note that the type fields defined are only valid within the encapsulated capabilities configuration setting string.

type	length	value
5	n	

The set of possible encapsulated fields is described below.

B.12.8.7.1 Concatenation support

If the value field is a 1 this modem can support concatenation; if a 0 it cannot.

type	length	on/off
1	1	1 or 0

Table B.12-2/J.116 – Sample capability encoding

Type	Length	Value (sub)type	Length	Value	
5					modem capability configuration setting
		1	1	1	concatenation supported

B.12.8.8 BWA CPE Modem Message Integrity Check (MIC) configuration setting

The value field contains the BWA CPE Modem message integrity check code. This is used to detect unauthorised modification or corruption of the configuration file.

type	length	value
6	16	d1 d2 .... d16

B.12.8.9 BWA BTS Modem Message Integrity Check (MIC) configuration setting

The value field contains the BWA BTS Modem message integrity check code. This is used to detect unauthorised modification or corruption of the configuration file.

type	length	value
7	16	d1 d2 .... d16

B.12.8.10 Vendor ID configuration setting

The value field contains the vendor identification specified by the three-byte vendor-specific Organisation Unique Identifier of the BWA CPE Modem MAC address.

type	length	value
8	3	v1, v2, v3

B.12.8.11 Software upgrade filename

The filename of the software upgrade file for the BWA CPE Modem. This is a filename only, not a complete path. The file should reside in the TFTP public directory.

type	length	value
9	n	filename

NOTE – Filename length MUST be less than or equal to 64 bytes.

B.12.8.12 SNMP write-access control

This object makes it possible to disable SNMP "Set" access to individual MIB objects. Each instance of this object controls access to all of the writeable MIB objects whose Object ID (OID) prefix matches. This object may be repeated to disable access to any number of MIB objects.

type	length	value
10	n	OID prefix plus control flag

where n is the size of the ASN.1 Basic Encoding Rules (ITU-T H.222.0 | ISO/IEC 13818-1) encoding of the OID prefix plus one byte for the control flag.

The control flag may take values:

0 – allow write-access.

1 – disallow write-access.

Any OID prefix may be used. The Null OID 0.0 may be used to control access to all MIB objects. (The OID 1.3.6.1 will have the same effect.)

When multiple instances of this object are present and overlap, the longest (most specific) prefix has precedence. Thus, one example might be:

someTable	disallow write-access
someTable.1.3	allow write-access

This example disallows access to all objects in someTable except for someTable.1.3.

B.12.8.13 SNMP MIB Object

This object allows arbitrary SNMP MIB objects to be Set via the TFTP-Registration process.

type	length	value
11	n	variable binding

where the value is an SNMP VarBind as defined in IETF RFC 1157. The VarBind is encoded in ASN.1 Basic Encoding Rules, just as it would be if part of an SNMP Set request.

The BWA CPE modem MUST treat this object as if it were part of an SNMP Set Request with the following caveats:

- It MUST treat the request as fully authorised (it cannot refuse the request for lack of privilege).
- SNMP Write-Control provisions (see previous subclause) do not apply.
- No SNMP response is generated by the BWA CPE Modem.

This object MAY be repeated with different VarBinds to "Set" a number of MIB objects. All such Sets MUST be treated as if simultaneous.

Each VarBind MUST be limited to 255 bytes.

B.12.8.14 Vendor-specific information

Vendor-specific information for BWA CPE modems, if present, MUST be encoded in the configuration file using the vendor-specific information code (43) following the rules defined in IETF RFC 1533. The vendor identifier field MUST be present if this configuration setting is used. This configuration setting MAY appear multiple times.

type	length	value
43	n	per vendor definition

B.12.8.15 Modem IP address

This object informs the BWA BTS Modem of the provisioned IP address of the BWA CPE modem.

type	length	value
12	4	IP Address

This object appears only in the Registration Request message.

This address plays no part in the protocols defined in this specification, but is included to assist with network management.

B.12.8.16 Service(s) not available response

This configuration setting MUST be included in the Registration Response message if the BWA BTS Modem is unable or unwilling to grant any of the requested classes of service that appeared in the Registration Request. Although the value applies only to the failed service class, the entire Registration Request MUST be considered to have failed (none of the class-of-service configuration settings are granted).

type	length	value
13	3	class ID, type, reason

where:

class ID is the class-of-service class from the request which is not available;

type is the specific class-of-service object within the class which caused the request to be rejected;

reason is the reason for the rejection from the following:

reason-other(1)

reason-unrecognised-configuration-setting(2)

reason-temporary(3)

reason-permanent(4)

The reason codes MUST be used in the following way.

- Reason-other(1) is used when none of the other reason codes apply.
- Reason-unrecognised-configuration-setting(2) is used when a class-of-service type is not recognised or when its value is outside of the specified range.
- Reason-temporary(3) indicates that the current loading of service IDs or traffic policies at the BWA BTS Modem prevents granting the request, but that the request might succeed at another time.
- Reason-permanent(4) indicates that, for policy, configuration, or BWA BTS Modem capabilities reasons, the request would never be granted unless the BWA BTS Modem were manually reconfigured or replaced.

B.12.8.17 CPE Ethernet MAC address

This object configures the BWA CPE Modem with the Ethernet MAC address of a CPE device (see subclause B.3.1.2.3.1). This object may be repeated to configure any number of CPE device addresses.

type	length	value
14	6	Ethernet MAC Address of CPE

This object appears only in the configuration file.

B.13 MAC sublayer service definition

The MAC sublayer will provide the following services, consistent with ISO/IEC 15802-1. This is an internal interface within the BWA CPE Modem and BWA BTS Modem and is provided for reference purposes only.

B.13.1 Service at the BWA CPE Modem

The following service primitives are provided by the MAC sublayer to the higher-layer protocol entity. These represent an abstraction of the service provided and do not imply a particular implementation.

MAC_CPE_MODEM_802_DATA.request

MAC_CPE_MODEM_DIX_DATA.request

MAC_CPE_MODEM_ATM_DATA.request

MAC_CPE_MODEM_802_DATA.indication

MAC_CPE_MODEM_DIX_DATA.indication

MAC_CPE_MODEM_ATM_DATA.indication

MAC_CPE_MODEM_DATA.acknowledgement

B.13.2 MAC_CPE_MODEM_802_DATA.request

Issued by the higher-layer to request transmission from the BWA CPE Modem on an upstream channel. Parameters:

- channel_ID – MAY be implicit if the device supports attachment to a single channel.
- service_ID.
- contention_and_acknowledgement_constraints – specifies whether or not this request MAY be satisfied in a contention interval. Ordinarily, the BWA CPE Modem will request that contention data be acknowledged by the BWA BTS Modem.
- destination_address.
- source_address (OPTIONAL) – if not explicitly overwritten, the address at this MSAP is used.
- LLC_pdu.
- padding (OPTIONAL) – MAY be used if the LLC PDU is less than 60 bytes and it is desired to maintain ISO/IEC 8802-3 transparency.
- frame_check_sequence (OPTIONAL) – MAY be supplied if ISO/IEC 8802-3 transparency is desired. Otherwise, a 32-bit CRC sum is calculated by the MAC sublayer.
- length.

B.13.3 MAC_CPE_MODEM_DIX_DATA.request

Issued by the higher-layer to request transmission from the BWA CPE Modem on an upstream channel. Parameters:

- channel_ID – MAY be implicit if the device supports attachment to a single channel.
- service_ID.
- contention_and_acknowledgement_constraints – specifies whether or not this request MAY be satisfied in a contention interval. Ordinarily, the BWA CPE Modem will request that contention data be acknowledged by the BWA BTS Modem.
- destination_address.
- source_address (OPTIONAL) – if not explicitly overwritten, the address at this MSAP is used.
- ethernet type.
- ethernet_dix_pdu.
- length.

B.13.4 MAC_CPE_MODEM_ATM_DATA.request

Issued by the higher-layer to request transmission from the BWA CPE Modem on an upstream channel. Parameters:

- channel_ID – MAY be implicit if the device supports attachment to a single channel.
- service_ID.
- contention_and_acknowledgement_constraints – specifies whether or not this request MAY be satisfied in a contention interval. Ordinarily, the BWA CPE Modem will request that contention data be acknowledged by the BWA BTS Modem.
- one or more ATM cells. Cells need not be within the same virtual circuit or virtual path.
- length.

B.13.5 MAC_CPE_MODEM_802_DATA.indication

Issued by the BWA CPE Modem MAC to indicate reception of data from the downstream channel. Parameters:

- channel_ID – MAY be implicit if the device supports attachment to a single channel.
- destination_address.
- source_address.
- LLC_pdu.
- padding (OPTIONAL) – MAY be present if the LLC PDU was less than 60 bytes and ISO/IEC 8802-3 transparency was desired.
- frame_check_sequence.
- length.

B.13.6 MAC_CPE_MODEM_DIX_DATA.indication

Issued by the BWA CPE Modem MAC to indicate reception of data from the downstream channel. Parameters:

- channel_ID – MAY be implicit if the device supports attachment to a single channel.
- destination_address.
- source_address.
- ethernet type.
- ethernet_dix_pdu.
- frame_check_sequence.
- length.

B.13.7 MAC_CPE_MODEM_ATM_DATA.indication

Issued by the BWA CPE Modem MAC to indicate reception of data on the downstream channel. Parameters:

- channel_ID – MAY be implicit if the device supports attachment to a single channel.
- service_ID.
- one or more ATM cells. Cells need not be within the same virtual circuit or virtual path.
- length.

B.13.8 MAC_CPE_MODEM_DATA.acknowledgement

Issued by the BWA CPE Modem MAC to indicate reception of an acknowledgement on the downstream channel. An acknowledgement is an information element in a MAP PDU (see B.6.4.1.1). The BWA BTS Modem MUST include this IE in response to an upstream data transmission that includes an acknowledgement request.

Parameters:

- channel_ID – The downstream channel on which the acknowledgement was received. May be implicit if the device supports attachment to a single channel.
- service_ID.
- length.

B.14 Example Burst Profiles

B.14.1 Introduction

Tables B.14-1 through B.14-4 contain example Channel Burst Profiles for various modulation format and symbol rate combinations. The column labelled Column #1 in Tables B.14-1 through B.14-4 corresponds to the Request burst type. The other columns correspond to the Communication (or Data) burst type. Table B.14-5 contains example Channel Burst Profiles corresponding to Power-Up burst types, or Acquisition burst types (for use on a new channel – or simply for refinement of user-unique parameters).

A burst length of 0 mini-slots in the Channel Profile means that the burst length is variable on that channel for that burst type, and will be assigned by the BWA BTS Modem for each burst.

A programmable 1024-bit-long preamble is included, common to the "immediately available" burst profiles, but with each burst profile able to specify the start location within this sequence of bits and the length of the preamble.

Table B.14-6 contains the frame formats for each of the symbol rates with QPSK modulation for the example Request burst and for three codeword lengths for the Communication bursts, with one codeword per burst. Additionally, frame formats are shown for each of the rates with two of the example codeword lengths with four codewords per burst. In each format example, the information rate of the burst is calculated and given in the table. For the Request burst, the 6 bytes of "data" are assumed to be the information, and the rest is overhead. In the Communication bursts, the preamble, spacing (guard time), FEC parity, and the example 6 bytes of MAC Header are assumed overhead for the purposes of calculating information rate.

Table B.14-7 is structured the same as Table B.14-6, but with the example formats for 16-QAM modulation.

B.14.2 Example Preamble Sequence

The following is the example 1024-bit preamble sequence for Tables B.14-1 through B.14-5:

Bits 1 through 128:

1100 1100 1111 0000 1111 1111 1100 0000 1111 0011 1111 0011 0011 0000 0000 1100

0011 0000 0011 1111 1111 1100 1100 1100 1111 0000 1111 0011 1111 0011 1100 1100

Bits 129 through 256:

0011 0000 1111 1100 0000 1100 1111 1111 0000 1100 1100 0000 1111 0000 0000 1100

0000 0000 1111 1111 1111 0011 0011 0011 1100 0011 1100 1111 1100 1111 0011 0000

Bits 257 through 384:

1100 0011 1111 0000 0011 0011 1111 1100 0011 0011 0000 0011 1100 0000 0011 0000

0000 1110 1101 0001 0001 1110 1110 0101 0010 0101 0010 0101 1110 1110 0010 1110

Bits 385 through 512:

0010 1110 1110 0010 0010 1110 1110 1110 1110 1110 0010 0010 0010 1110 1110 0010

1110 1110 1110 0010 1110 0010 1110 0010 0010 0010 0010 1110 0010 0010 1110 0010

Bits 513 through 640:

0010 0010 1110 1110 1110 1110 1110 1110 0010 1110 0010 1110 0010 1110 1110 0010

0010 1110 1110 0010 1110 1110 1110 0010 1110 1110 0010 1110 0010 0010 1110 0010

Bits 641 through 768:

0010 1110 1110 1110 0010 0010 0010 1110 0010 1110 1110 1110 1110 0010 0010 1110

0010 1110 0010 0010 0010 1110 1110 0010 0010 0010 0010 1110 0010 0010 0010 0010

Bits 769 through 896:

0010 1110 1110 1110 1110 1110 1110 0010 1110 0010 1110 0010 1110 1110 0010 0010

1110 1110 0010 1110 1110 1110 0010 1110 1110 0010 1110 0010 0010 1110 0010 0010

Bits 897 through 1024:

1110 1110 1110 0010 0010 0010 1110 0010 1110 1110 1110 1110 0010 0010 1110 0010

1110 0010 0010 0010 1110 1110 0010 0010 0010 0010 1110 0010 0010 0010 0010 1110

B.14.3 Example Burst Profiles

Table B.14-1/J.116 – Example Channel Burst Parameter Values for QPSK Operation at 160, 320, and 640 ksym/s

Parameter	Config. Settings	#1	#2	#3	#4	#5
Modulation	QPSK, 16 QAM	QPSK	QPSK	QPSK	QPSK	QPSK
Diff Enc	On/Off	Off	Off	Off	Off	Off
Symbol Rate	5 configuration settings	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s
Preamble Length	0, 4-1024 bits	56 bits	64 bits	64 bits	64 bits	64 bits
Preamble Start Location	1024 configuration settings	15	7	7	7	7
Preamble Values	1024 programmable bits	(Note 3)	(Note 3)	(Note 3)	(Note 3)	(Note 3)
FEC On/Off	On/Off	Off	On	On	On	On
FEC Codeword Information Bytes (k)	1 to 255	N/A	32	56	64	220
FEC Error Correction (T bytes)	0 to 10	N/A	4	7	8	10
Last Codeword Length	Fixed or Shortened	N/A	Fixed	Fixed	Fixed	Fixed
Scrambler On/Off	On/Off	On	On	On	On	On
Scrambler Seed	15 bits (Note 2)	default	default	default	default	default
Burst Length mini-slots (Note 1)	0 to 255	3	0	0	0	0

NOTE 1 – A burst length of 0 mini-slots in the Channel Profile means that the burst length is variable on that channel for that burst type.

NOTE 2 – 15 bits in a 16-bit field.

NOTE 3 – Refer to B.14.2.

Table B.14-2/J.116 – Example Channel Burst Parameter Values for QPSK Operation at 1.28 and 2.56 Msym/s

Parameter	Config. Settings	#1	#2	#3	#4	#5
Modulation	QPSK, 16 QAM	QPSK	QPSK	QPSK	QPSK	QPSK
Diff Enc	On/Off	Off	Off	Off	Off	Off
Symbol Rate	5 configuration settings	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s
Preamble Length	0, 4-1024 bits	48 bits	96 bits	96 bits	96 bits	96 bits
Preamble Start Location	1024 configuration settings	19	125	125	125	125
Preamble Values	1024 programmable bits	(Note 3)	(Note 3)	(Note 3)	(Note 3)	(Note 3)
FEC On/Off	On/Off	Off	On	On	On	On
FEC Codeword Information Bytes (k)	1 to 255	N/A	40	56	64	220
FEC Error Correction (T bytes)	0 to 10	N/A	4	4	4	10
Last Codeword Length	Fixed or Shortened	N/A	Fixed	Fixed	Fixed	Fixed
Scrambler On/Off	On/Off	On	On	On	On	On
Scrambler Seed	15 bits (Note 2)	default	default	default	default	default
Burst Length mini-slots (Note 1)	0 to 255	4	0	0	0	0

NOTE 1 – A burst length of 0 mini-slots in the Channel Profile means that the burst length is variable on that channel for that burst type.

NOTE 2 – 15 bits in a 16-bit field.

NOTE 3 – Refer to B.14.2.

Table B.14-3/J.116 – Example Channel Burst Parameter Values for 16-QAM Operation at 160, 320, and 640 ksym/s

Parameter	Config. Settings	#1	#2	#3	#4	#5
Modulation	QPSK, 16 QAM	16 QAM	16 QAM	16 QAM	16 QAM	16 QAM
Diff Enc	On/Off	Off	Off	Off	Off	Off
Symbol Rate	5 configuration settings	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s	160, 320 or 640 ksym/s
Preamble Length	0, 4-1024 bits	80 bits	128 bits	128 bits	128 bits	128 bits
Preamble Start Location	1024 configuration settings	429	385	385	385	385
Preamble Values	1024 programmable bits	(Note 3)	(Note 3)	(Note 3)	(Note 3)	(Note 3)
FEC On/Off	On/Off	Off	On	On	On	On
FEC Codeword Information Bytes (k)	1 to 255	N/A	32	56	64	220
FEC Error Correction (T bytes)	0 to 10	N/A	4	7	8	10
Last Codeword Length	Fixed or Shortened	N/A	Fixed	Fixed	Fixed	Fixed
Scrambler On/Off	On/Off	On	On	On	On	On
Scrambler Seed	15 bits (Note 2)	default	default	default	default	default
Burst Length mini-slots (Note 1)	0 to 255	2	0	0	0	0

NOTE 1 – A burst length of 0 mini-slots in the Channel Profile means that the burst length is variable on that channel for that burst type.

NOTE 2 – 15 bits in a 16-bit field.

NOTE 3 – Refer to B.14.2.

Table B.14-4/J.116 – Example Channel Burst Parameter Values for 16-QAM Operation at 1.28 and 2.56 Msym/s

Parameter	Config. Settings	#1	#2	#3	#4	#5
Modulation	QPSK, 16 QAM	16 QAM	16 QAM	16 QAM	16 QAM	16 QAM
Diff Enc	On/Off	Off	Off	Off	Off	Off
Symbol Rate	5 configuration settings	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s	1.28 or 2.56 Msym/s
Preamble Length	0, 4-1024 bits	144 bits	192 bits	192 bits	192 bits	192 bits
Preamble Start Location	1024 configuration settings	709	621	621	621	621
Preamble Values	1024 programma-ble bits	(Note 3)	(Note 3)	(Note 3)	(Note 3)	(Note 3)
FEC On/Off	On/Off	Off	On	On	On	On
FEC Codeword Information Bytes (k)	1 to 255	N/A	40	56	64	220
FEC Error Correction (T bytes)	0 to 10	N/A	4	4	4	10
Last Codeword Length	Fixed or Shortened	N/A	Fixed	Fixed	Fixed	Fixed
Scrambler On/Off	On/Off	On	On	On	On	On
Scrambler Seed	15 bits (Note 2)	default	default	default	default	default
Burst Length mini-slots (Note 1)	0 to 255	4	0	0	0	0

NOTE 1 – A burst length of 0 mini-slots in the Channel Profile means that the burst length is variable on that channel for that burst type.

NOTE 2 – 15 bits in a 16-bit field.

NOTE 3 – Refer to B.14.2.

Table B.14-5/J.116 – Example Channel Burst Parameter Values for Power-Up and Acquisition in a New Channel

Parameter	Config. Settings	#1	#2	#3	#4
Modulation	QPSK, 16 QAM	QPSK	QPSK	16 QAM	16 QAM
Diff Enc	On/Off	Off	Off	Off	Off
Symbol Rate	5 configuration settings	160, 320 or 640 ksym/s	1.28 or 2.56 Msym/s	160, 320 or 640 ksym/s	1.28 or 2.56 Msym/s
Preamble Length	0, 4-1024 bits	1024 bits	1024 bits	1024 bits	1024 bits
Preamble Start Location	1024 configuration settings	1	1	1	1
Preamble Values	1024 programmable bits	(Note 3)	(Note 3)	(Note 3)	(Note 3)
FEC On/Off	On/Off	On	On	On	On
FEC Codeword Information Bytes (k)	1 to 255	60	60	60	60
FEC Error Correction (T bytes)	0 to 10	10	10	10	10
Last Codeword Length	Fixed or Shortened	Fixed	Fixed	Fixed	Fixed
Scrambler On/Off	On/Off	On	On	On	On
Scrambler Seed	15 bits (Note 2)	default	default	default	default
Burst Length mini-slots (Note 1)	0 to 255	42	53	21	27

NOTE 1 – A burst length of 0 mini-slots in the Channel Profile means that the burst length is variable on that channel for that burst type.

NOTE 2 – 15 bits in a 16-bit field.

NOTE 3 – Refer to B.14.2.

Table B.14-6/J.116 – Frame Format Examples with QPSK Operation

Parameter	160 ksym/s	320 ksym/s	640 ksym/s	1.28 Msym/s	2.56 Msym/s
Request Burst					
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (2)	8 (2)	8 (2)	16 (4)	16 (4)
data symbols (bytes)	24 (6)	24 (6)	24 (6)	24 (6)	24 (6)
preamble symbols (bytes)	28 (7)	28 (7)	28 (7)	24 (6)	24 (6)
total symbols (bytes)	60 (15)	60 (15)	60 (15)	64 (16)	64 (16)
total burst duration (mini-slots)	3	3	3	4	4
total burst duration (microseconds)	375	187.5	93.75	50	25
information rate (6 bytes per burst)	128 kbit/s	256 kbit/s	512 kbit/s	960 kbit/s	1.92 Mbit/s
Communication Burst					
codewords/burst	1*	1*	1*	1*	1*
errors corrected per codeword	4	4	4	4	4
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (2)	8 (2)	8 (2)	16 (4)	16 (4)
data symbols (bytes)	128 (32)	128 (32)	128 (32)	160 (40)	160 (40)
parity symbols (bytes)	32 (8)	32 (8)	32 (8)	32 (8)	32 (8)
preamble symbols (bytes)	32 (8)	32 (8)	32 (8)	48 (12)	48 (12)
total symbols (bytes)	200 (50)	200 (50)	200 (50)	256 (64)	256 (64)
total burst duration (mini-slots)	2 + 8 = 10	2 + 8 = 10	2 + 8 = 10	4 + 12 = 16	4 + 12 = 16
total burst duration (microseconds)	1250	625	312.5	200	100
information rate (excluding MAC Header)	166.4 kbit/s	332.8 kbit/s	665.6 kbit/s	1.360 Mbit/s	2.720 Mbit/s

* The numbers in the table are given for a single codeword, but more codewords can be added, with the same data and parity lengths as given in the table, to create longer bursts.

Table B.14-6/J.116 – Frame Format Examples with QPSK Operation *(continued)*

Parameter	160 ksym/s	320 ksym/s	640 ksym/s	1.28 Msym/s	2.56 Msym/s
Communication Burst					
codewords/burst	1*	1*	1*	1*	1*
errors corrected per codeword	8	8	8	4	4
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (2)	8 (2)	8 (2)	16 (4)	16 (4)
data symbols (bytes)	256 (64)	256 (64)	256 (64)	256 (64)	256 (64)
parity symbols (bytes)	64 (16)	64 (16)	64 (16)	32 (8)	32 (8)
preamble symbols (bytes)	32 (8)	32 (8)	32 (8)	48 (12)	48 (12)
total symbols (bytes)	360 (90)	360 (90)	360 (90)	352 (88)	352 (88)
total burst duration (mini-slots)	2 + 16 = 18	2 + 16 = 18	2 + 16 = 18	4 + 18 = 22	4 + 18 = 22
total burst duration (microseconds)	2250	1125	562.5	275	137.5
information rate (excluding MAC Header)	206.2 kbit/s	412.4 kbit/s	824.9 kbit/s	1.687 Mbit/s	3.375 Mbit/s
Communication Burst					
codewords/burst	1*	1*	1*	1*	1*
errors corrected per codeword	10	10	10	10	10
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (2)	8 (2)	8 (2)	16 (4)	16 (4)
data symbols (bytes)	880 (220)	880 (220)	880 (220)	880 (220)	880 (220)
parity symbols (bytes)	80 (20)	80 (20)	80 (20)	80 (20)	80 (20)
preamble symbols (bytes)	32 (8)	32 (8)	32 (8)	48 (12)	48 (12)
total symbols (bytes)	1000 (250)	1000 (250)	1000 (250)	1024 (256)	1024 (256)
total burst duration (mini-slots)	2 + 48 = 50	2 + 48 = 50	2 + 48 = 50	4 + 60 = 64	4 + 60 = 64
total burst duration (microseconds)	6250	3125	1562.5	800	400
information rate (excluding MAC Header)	273.9 kbit/s	547.8 kbit/s	1.096 Mbit/s	2.140 Mbit/s	4.280 Mbit/s

* The numbers in the table are given for a single codeword, but more codewords can be added, with the same data and parity lengths as given in the table, to create longer bursts.

Table B.14-6/J.116 – Frame Format Examples with QPSK Operation *(concluded)*

Parameter	160 ksym/s	320 ksym/s	640 ksym/s	1.28 Msym/s	2.56 Msym/s
Communication Burst					
codewords/burst	4*	4*	4*	4*	4*
errors corrected per codeword	8	8	8	4	4
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (2)	8 (2)	8 (2)	16 (4)	16 (4)
data symbols (bytes)	1024 (256)	1024 (256)	1024 (256)	1024 (256)	1024 (256)
parity symbols (bytes)	256 (64)	256 (64)	256 (64)	128 (32)	128 (32)
preamble symbols (bytes)	32 (8)	32 (8)	32 (8)	48 (12)	48 (12)
total symbols (bytes)	1320 (330)	1320 (330)	1320 (330)	1216 (304)	1216 (304)
total burst duration (mini-slots)	2 + 16*4 = 66	2 + 16*4 = 66	2 + 16*4 = 66	4 + 18*4 = 76	4 + 18*4 = 76
total burst duration (microseconds)	8250	4125	2062.5	950	475
information rate (excluding MAC Header)	242.4 kbit/s	484.8 kbit/s	969.7 kbit/s	2.105 Mbit/s	4.211 Mbit/s
Communication Burst					
codewords/burst	4*	4*	4*	4*	1*
errors corrected per codeword	10	10	10	10	10
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (2)	8 (2)	8 (2)	16 (4)	16 (4)
data symbols (bytes)	3520 (880)	3520 (880)	3520 (880)	3520 (880)	3520 (880)
parity symbols (bytes)	320 (80)	320 (80)	320 (80)	320 (80)	320 (80)
preamble symbols (bytes)	32 (8)	32 (8)	32 (8)	48 (12)	48 (12)
total symbols (bytes)	3880 (970)	3880 (970)	3880 (970)	3904 (976)	3904 (976)
total burst duration (mini-slots)	2 + 48*4 = 194	2 + 48*4 = 194	2 + 48*4 = 194	4 + 60*4 = 244	4 + 60*4 = 244
total burst duration (microseconds)	24 250	12 125	6062.5	3050	1525
information rate (excluding MAC Header)	288.3 kbit/s	576.7 kbit/s	1.153 Mbit/s	2.292 Mbit/s	4.585 Mbit/s

* The numbers in the table are given for four codewords per burst, but more or fewer codewords can be used, with the same data and parity lengths as given in the table.

Table B.14-7/J.116 – Frame Format Examples with 16-QAM Operation

Parameter	160 ksym/s	320 ksym/s	640 ksym/s	1.28 Msym/s	2.56 Msym/s
Request Burst					
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (4)	8 (4)	8 (4)	16 (8)	16 (8)
data symbols (bytes)	12 (6)	12 (6)	12 (6)	12 (6)	12 (6)
preamble symbols (bytes)	20 (10)	20 (10)	20 (10)	36 (18)	36 (18)
total symbols (bytes)	40 (20)	40 (20)	40 (20)	64 (32)	64 (32)
total burst duration (mini-slots)	2	2	2	4	4
total burst duration (microseconds)	250	125	62.5	50	25
information rate (6 bytes per burst)	192 kbit/s	384 kbit/s	768 kbit/s	960 kbit/s	1.920 Mbit/s
Communication Burst					
codewords/burst	1*	1*	1*	1*	1*
errors corrected per codeword	4	4	4	4	4
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (4)	8 (4)	8 (4)	16 (8)	16 (8)
data symbols (bytes)	64 (32)	64 (32)	64 (32)	80 (40)	80 (40)
parity symbols (bytes)	16 (8)	16 (8)	16 (8)	16 (8)	16 (8)
preamble symbols (bytes)	32 (16)	32 (16)	32 (16)	48 (24)	48 (24)
total symbols (bytes)	120 (60)	120 (60)	120 (60)	160 (80)	160 (80)
total burst duration (mini-slots)	2 + 4 = 6	2 + 4 = 6	2 + 4 = 6	4 + 6 = 10	4 + 6 = 10
total burst duration (microseconds)	750	375	187.5	125	62.5
information rate (excluding MAC Header)	277.3 kbit/s	554.7 kbit/s	1.109 Mbit/s	2.176 Mbit/s	4.352 Mbit/s
* The numbers in the table are given for a single codeword, but more codewords can be added, with the same data and parity lengths as given in the table, to create longer bursts.					

Table B.14-7/J.116 – Frame Format Examples with 16-QAM Operation *(continued)*

Parameter	160 ksym/s	320 ksym/s	640 ksym/s	1.28 Msym/s	2.56 Msym/s
Communication Burst					
codewords/burst	1*	1*	1*	1*	1*
errors corrected per codeword	7	7	7	4	4
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (4)	8 (4)	8 (4)	16 (8)	16 (8)
data symbols (bytes)	128 (64)	128 (64)	128 (64)	128 (64)	128 (64)
parity symbols (bytes)	32 (16)	32 (16)	32 (16)	16 (8)	16 (8)
preamble symbols (bytes)	32 (16)	32 (16)	32 (16)	48 (24)	48 (24)
total symbols (bytes)	200 (100)	200 (100)	200 (100)	208 (104)	208 (104)
total burst duration (mini-slots)	2 + 8 = 10	2 + 8 = 10	2 + 8 = 10	4 + 9 = 13	4 + 9 = 13
total burst duration (microseconds)	1250	625	312.5	162.5	81.25
information rate (excluding MAC Header)	371.2 kbit/s	742.4 kbit/s	1.455 Mbit/s	2.855 Mbit/s	5.711 Mbit/s
Communication Burst					
codewords/burst	1*	1*	1*	1*	1*
errors corrected per codeword	10	10	10	10	10
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (4)	8 (4)	8 (4)	16 (8)	16 (8)
data symbols (bytes)	440 (220)	440 (220)	440 (220)	440 (220)	440 (220)
parity symbols (bytes)	40 (20)	40 (20)	40 (20)	40 (20)	40 (20)
preamble symbols (bytes)	32 (16)	32 (16)	32 (16)	48 (24)	48 (24)
total symbols (bytes)	520 (260)	520 (260)	520 (260)	544 (272)	544 (272)
total burst duration (mini-slots)	2 + 24 = 26	2 + 24 = 26	2 + 24 = 26	4 + 30 = 34	4 + 30 = 34
total burst duration (microseconds)	3250	1625	812.5	425	212.5
information rate (excluding MAC Header)	526.8 kbit/s	1.054 Mbit/s	2.107 Mbit/s	4.028 Mbit/s	8.056 Mbit/s

* The numbers in the table are given for a single codeword, but more codewords can be added, with the same data and parity lengths as given in the table, to create longer bursts.

Table B.14-7/J.116 – Frame Format Examples with 16-QAM Operation *(concluded)*

Parameter	160 ksym/s	320 ksym/s	640 ksym/s	1.28 Msym/s	2.56 Msym/s
Communication Burst					
codewords/burst	4*	4*	4*	4*	4*
errors corrected per codeword	7	7	7	4	4
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (4)	8 (4)	8 (4)	16 (8)	16 (8)
data symbols (bytes)	512 (256)	512 (256)	512 (256)	512 (256)	512 (256)
parity symbols (bytes)	128 (64)	128 (64)	128 (64)	64 (32)	64 (32)
preamble symbols (bytes)	32 (16)	32 (16)	32 (16)	48 (24)	48 (24)
total symbols (bytes)	680 (340)	680 (340)	680 (340)	640 (320)	640 (320)
total burst duration (mini-slots)	2 + 8*4 = 34	2 + 8*4 = 34	2 + 8*4 = 34	4 + 9*4 = 40	4 + 9*4 = 40
total burst duration (microseconds)	4250	2125	1062.5	500	250
information rate (excluding MAC Header)	470.6 kbit/s	941.2 kbit/s	1.882 Mbit/s	4.000 Mbit/s	8.000 Mbit/s
Communication Burst					
codewords/burst	4*	4*	4*	4*	4*
errors corrected per codeword	10	10	10	10	10
spacing symbols (bytes) i.e. (guard time symbols -1)	8 (4)	8 (4)	8 (4)	16 (8)	16 (8)
data symbols (bytes)	1760 (880)	1760 (880)	1760 (880)	1760 (880)	1760 (880)
parity symbols (bytes)	160 (80)	160 (80)	160 (80)	160 (80)	160 (80)
preamble symbols (bytes)	32 (16)	32 (16)	32 (16)	48 (24)	48 (24)
total symbols (bytes)	1960 (980)	1960 (980)	1960 (980)	1984 (992)	1984 (992)
total burst duration (mini-slots)	2 + 24*4 = 98	2 + 24*4 = 98	2 + 24*4 = 98	4 + 30*4 = 124	4 + 30*4 = 124
total burst duration (microseconds)	12 250	6125	3062.5	1550	775
information rate (excluding MAC Header)	570.8 kbit/s	1.142 Mbit/s	2.283 Mbit/s	4.511 Mbit/s	9.022 Mbit/s
* The numbers in the table are given for four codewords per burst, but more or fewer codewords can be used, with the same data and parity lengths as given in the table.					

APPENDIX I

Wireless transmission characteristics

This Recommendation is complementary to ITU-R F.1499. This appendix provides an Informative summary of the Normative clauses of ITU-R F.1499.

Although references to this appendix are made only in Annex B, it should be noted that the information in this appendix is also applicable to Annex A.

Where reference to Appendix I is made in Annex B, the text to which it refers can be found below, under the same heading and subclause number as used in Annex B.

I.1 Assumed upstream and downstream RF channel transmission characteristics (values from ITU-R F.1499)

See Table I.1.

Table I.1/J.116 – RF channel transmission characteristics

Parameter	Value
Frequency range	2.5-66 GHz is assumed (including the LMDS, LMCS and MMDS bands)
Upstream RF channel spacing (design bandwidth)	up to 26 MHz
Downstream RF channel spacing (design bandwidth)	up to 40 MHz
Propagation delay from the BTS to the most distant CPE	≤0.05 ms (typically much less)
Maximum rain attenuation	30 dB
Maximum rain fade rate	5 dB per s
Main transmission mechanism	line-of-sight

I.2 ref.: B.2.1 Broadband wireless access (BWA) network

The broadband wireless access (BWA) system uses time division multiple access (TDMA). The key functional characteristics are the following:

- one- and two-way wireless transmission;
- downstream uses TDM (time division multiplex);
- upstream uses TDMA (time division multiple access);
- frequency bands between 2.5 to 66 GHz are most appropriate, subject to their being allocated to the fixed service;
- a BTS service area is called a cell, with a cell radius typically <15 km, depending on rain regions and the availability requirement;
- a cell may be divided into multiple sectors;
- the system must be able to combat rain fades of 30 dB and a fade rate of 5 dB/s.

I.3 ref.: B.2.2.1 Frequency plan

Frequency bands between 2.5 GHz and 66 GHz (e.g. Local Multipoint Distribution System (LMDS), Local Multipoint Communication System (LMCS) and Multichannel Multipoint Distribution System (MMDS) frequency bands) throughout the world are ideal for BWA applications. These types of systems form part of what is known as multimedia wireless systems (MWS). Considering the various RF bands to be used for BWA applications, it is desirable to define the intermediate frequency (IF) for the interface between the modem units and the RF units; however, the specific implementation of the IF is left to vendors.

I.4 ref.: B.4.2.2.4 Upstream Frequency Agility and Range

The upstream PMD sublayer MUST support operation over the frequency range of 2.5-40 GHz edge to edge.

I.5 ref.: Table B.4-7

Electrical RF Output from BWA CPE

Parameter	Value
Frequency	2.5 to 40 GHz is assumed.
Minimum Level range (one channel)	–27 to +17 dBm (16 QAM) –30 to +20 dBm (QPSK)

I.6 ref.: B.4.3.3 Downstream Frequency Plan

The downstream frequency should be in the range 2.5 to 40 GHz with channel bandwidth up to 40 MHz.

I.7 ref.: Table B.4-8

BWA BTS RF Output

Parameter	Value
Centre Frequency (fc)	2.5 to 40 GHz ± 5 ppm
Transmit Power Level (at tx antenna flange)	>10 dBm

I.8 ref.: Table B.4-9

RF Input to BWA CPE

Parameter	Value
Centre Frequency	2.5 to 40 GHz ± 5 ppm

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